Electric vehicle charging in Europe

Research report prepared for the European Parking Association

by Erasmus Centre for Urban, Port and Transport Economics

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Introduction to report

In December 2021, the EPA commissioned Erasmus UPT to conduct research on the theme of electric vehicle charging.

Research goals

- Provide an overview of state of the art of electric vehicle charging infrastructure in Europe
- Show EU policy makers both strengths and weaknesses of the system and the potential role of parking

Research methodology

1. Desk research of existing literature and data
2. Semi-structured interviews representing key stakeholder groups
3. Collection of primary survey data in collaboration with national parking associations linked to the EPA

Report structure

1. Electric vehicle trends
2. Trends in electric vehicle charging
3. Rollout of public charging infrastructure
4. Results of the EPA survey
5. Role of the parking sector
6. Key takeaways

Electric vehicle trends

A primer on electric vehicles

Electric vehicles that can be plugged into charging points include battery electric vehicles (BEVs) and plug-in hybrids (PHEVs). They function and perform differently from one another, as seen in the table below[1], resulting in market differences.

	Engine type	Emission production	Driving range	Model availability	Pricing
Battery electric	Electric engine powered by batteries that need to be charged	Emits zero greenhouse gases	Standard: 100 – 400 km Premium: 500 – 700 km	41 models from large OEMs	Standard: 25,000 – 40,000 euros Premium: 70,000 – 100,000 euros
Plug-in hybrid	Parallel configuration, utilizing both an internal combustion and electric engine	Emits zero greenhouse gases only on electric mode	Full electric mode: 30 – 70 km	49 models from large OEMs	30,000 - 150,000 euros

A reality check on PHEVs [2, 3]

While PHEVs have potential to decrease fuel consumption and associated emissions and air pollution, their benefits are often overstated, leading to unrealistic emission ratings. A 2022 study by the International Council for Clean Transportation examining their real-world usage has shown that only 45-49% of distances are actually driven on the electric motor for private cars, compared to assumptions of 70-85%. User behavior, among other factors like the lack of fast charging capabilities and limited electric ranges, make it so that private PHEVs consume three times more fuel than currently assumed by regulatory authorities.

The battery is the main cost driver of the electric vehicle and is what determines its performance.

Battery costs [4, 5, 6]

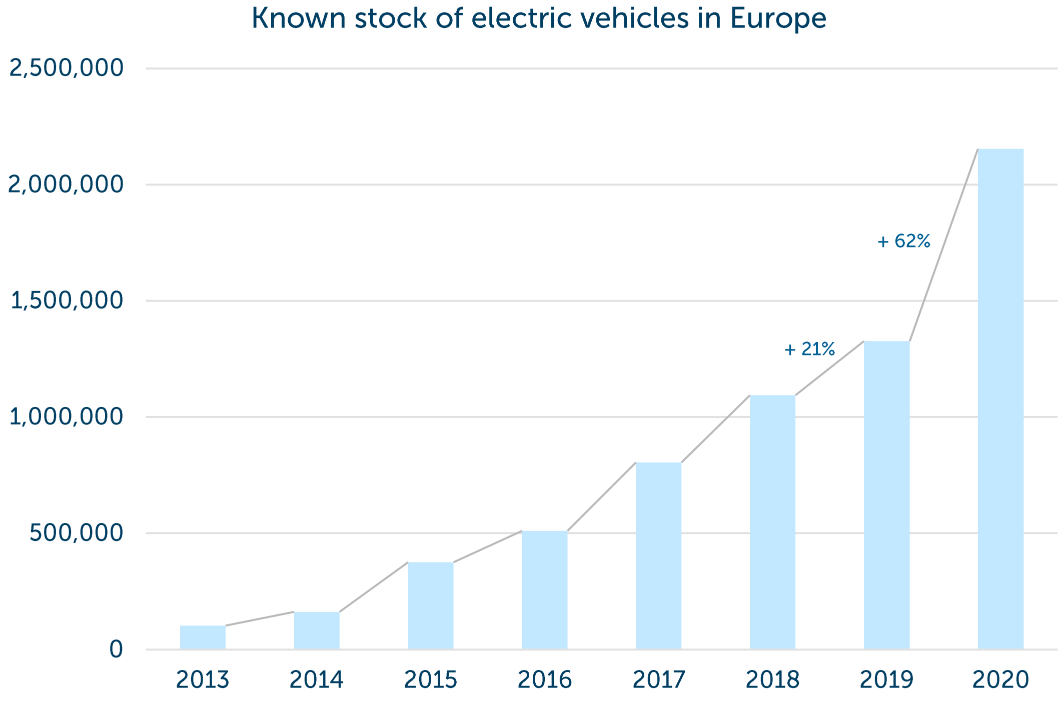
According to McKinsey, the cost of the battery makes up 35-45% of the total cost of an EV. Between 2010 and 2021, the price of lithium-ion batteries declined by 89% in real terms. Reductions in battery prices over the years are generally expected, although not as major, bringing down prices. It is necessary to note however that the cost of batteries has more than doubled between the first quarter of 2022 and 2021 due sanctions on Russian metals and supply chain disruptions.

Limits to driving range [7, 8, 9]

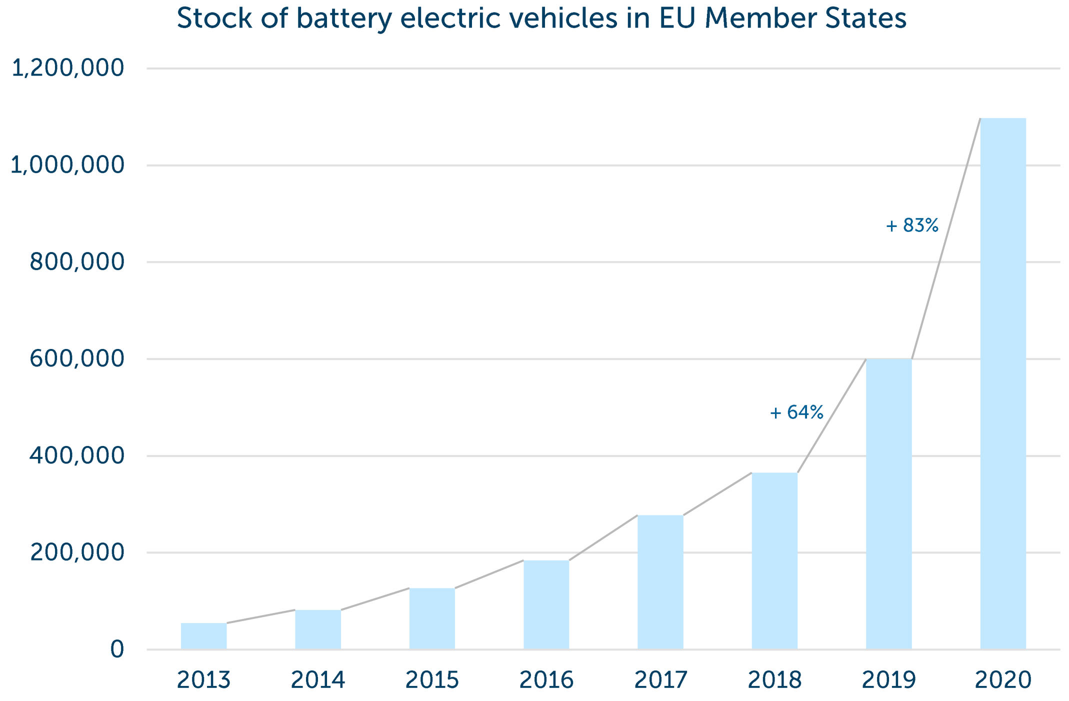
While decreases in battery prices are expected to make larger batteries and longer ranges more affordable, there are limits to the development of driving range. First, the average consumer does not require much range beyond what is already on offer and standard, especially with improvements in charging infrastructure. Second, there are design considerations. For example, batteries can make EVs significantly heavier than ICE vehicles (around three times). Here, only incremental improvements are expected.

Electric vehicle stock

Electric vehicles make up only 1.1% of the EU's total passenger car fleet. However, the number of electric vehicles in Europe has seen strong growth over the years, exceeding 2.1 million passenger vehicles in 2020.[10] While 53% percent of these vehicles were plug-in hybrids according to recent data published by the European Automobile Manufacturers' Association, the number of BEVs is growing rapidly – between 2019 and 2020, EU Member States saw an 83% rise in BEVs.



Source: Eurostat [10]

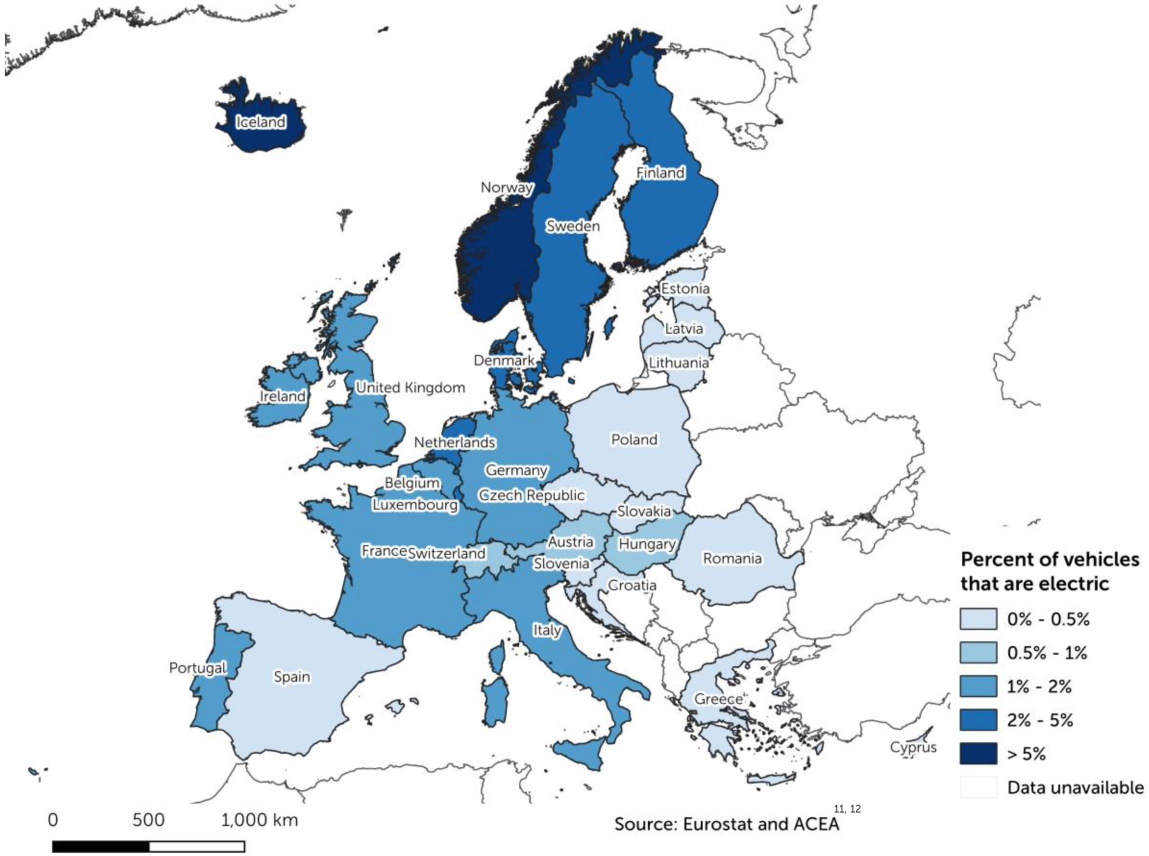


Source: Eurostat [10]

Electric vehicle stock

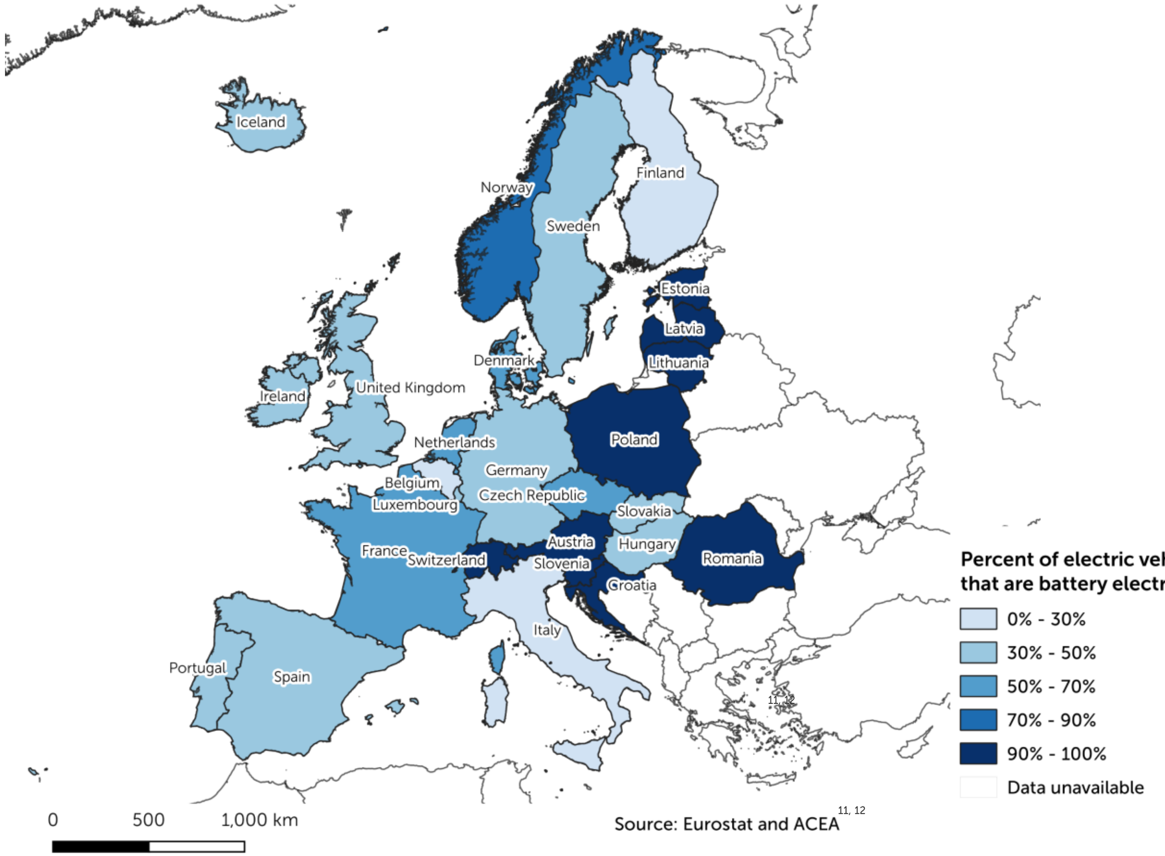
The composition of the passenger vehicle fleet differs greatly by country. Northern European countries tend to have the highest proportion of EVs in their fleet, with Norway and Iceland being clear outliers at 17% and 7% respectively. At the other end of the spectrum, we see Eastern European countries lagging behind, well below the average of 1.8%. However, Eastern European countries see less variety in the composition of the EV fleet with a higher ratio of BEVs to PHEVs.

Percentage of vehicle stock that is electric (2020)



Source: Eurostat and ACEA [11, 12]

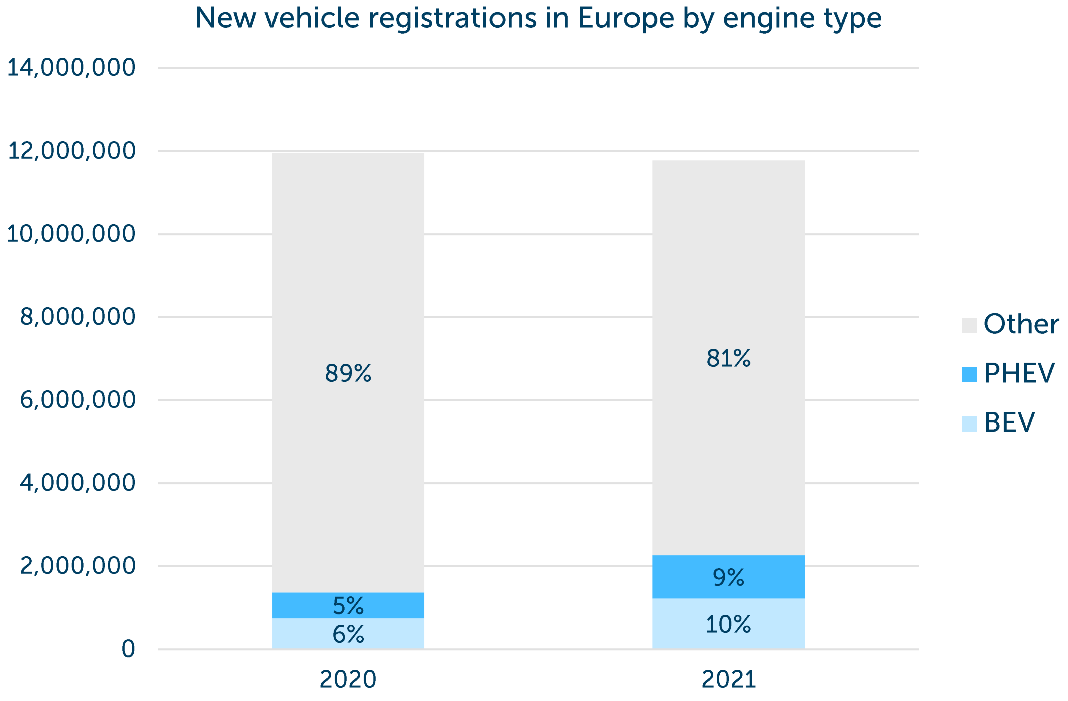
Percentage of electric vehicle stock that is battery electric (2020)



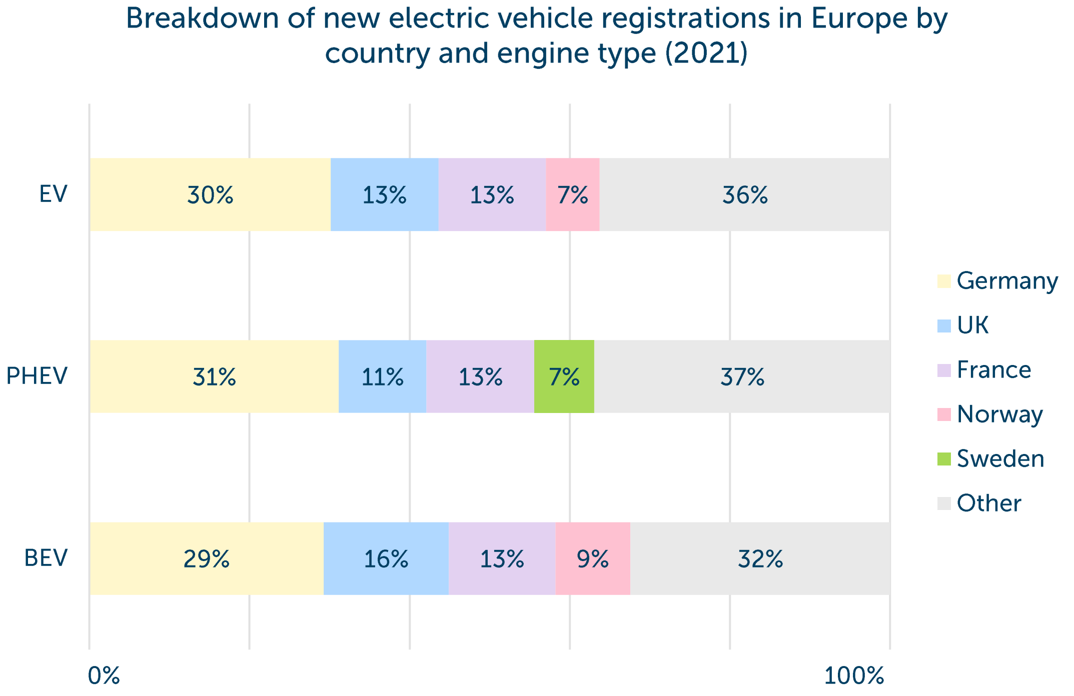
Source: Eurostat and ACEA [11, 12]

New electric vehicle registrations

In 2021, 19% of new vehicle registrations were attributed to EVs, with more than 2.2 million BEVs and PHEVs sold. Of these new EV registrations, 64% were concentrated in just four countries: Germany, the UK, France, and Norway. Whereas these countries saw hundreds of thousands of new EVs being sold, countries like Cyprus and Bulgaria saw no more than 600 registrations combined.



Source: ACEA [13]



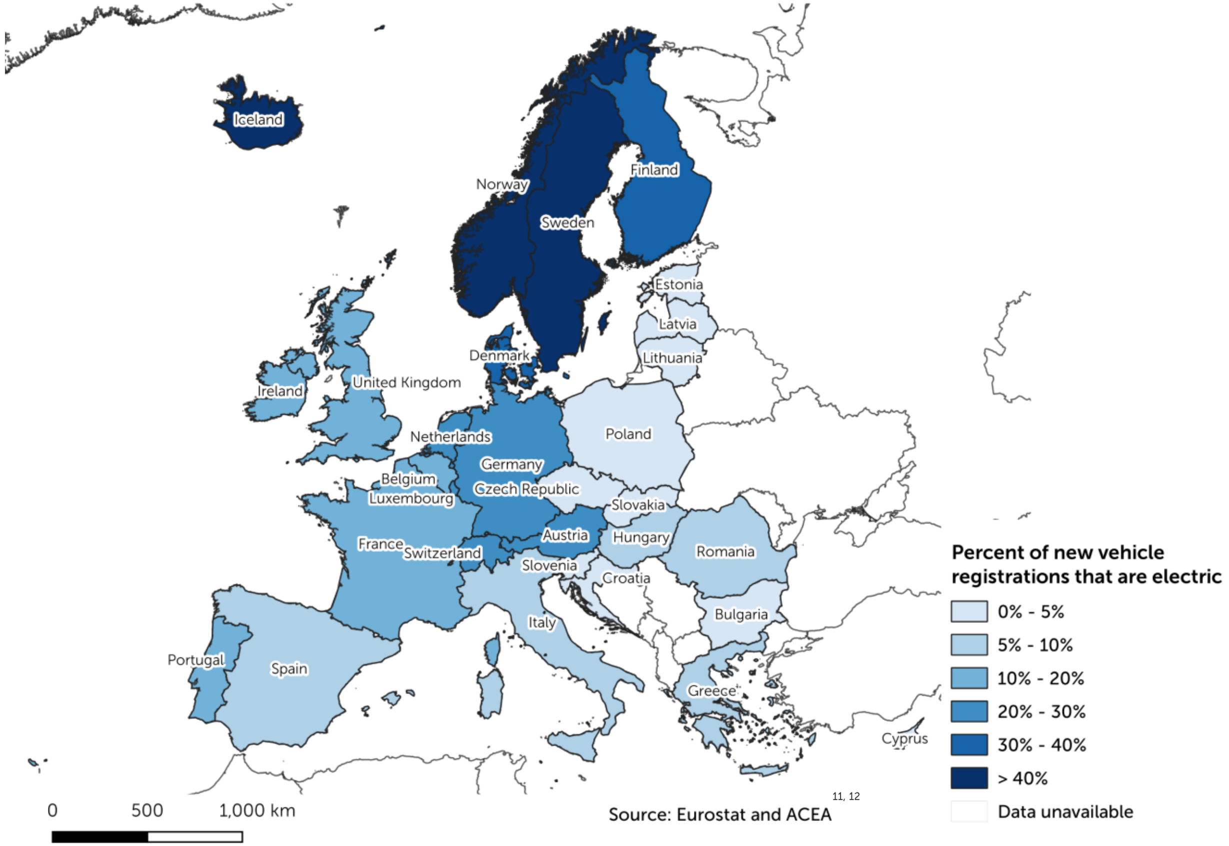
Source: ACEA [13]

New electric vehicle registrations from recent years have been primarily made up of BEVs, although there is some variance. In countries like Greece, Belgium, and Finland, sales of PHEVs constitute more than twice the amount of BEVs, whereas in Slovenia and Croatia BEVs are sold between 3-9 times more than PHEVs.[13]

New electric vehicle registrations

Significant differences between countries exist. Norway is by far the most striking with new EV sales making up 86% of total vehicle sales, followed by Iceland and Sweden at 55% and 45% respectively. Eastern European countries lag behind in this regard, with countries like Cyprus, Bulgaria, and Estonia seeing no more than 3% of new vehicle sales attributed to EVs compared to the European average of 19%. This is no surprise given gaps in affordability and policy support.

Percentage of new vehicle registrations that are electric (2021)



Source: Eurostat and ACEA [11, 12]

Why are more people buying electric vehicles? [14, 15, 16]

There are a variety of factors that might explain why the uptake of EVs has grown. While crucial factors like the development of charging infrastructure stand in the way of its potential, owning an EV is nevertheless becoming more desirable.

Consumers have a wider array of models to choose from (models on offer have more than doubled between 2019 and 2020), the prices of which are significantly decreasing. While it is true that EVs can still be more expensive that ICE vehicles, they bring along a lower cost of ownership given less maintenance needs, which is especially enticing in the case of high-mileage fleets. In addition, consumers are becoming more aware of climate change and purchases are becoming more eco-conscious.

	Factors affecting EV uptake				
	Economic	Non-financial	Individual	Spatial & built environment	Technical
Examples	Upfront costs, operation and maintenance costs, insurance costs	Comfort, convenience	Awareness, environmental attitudes, socio-demographics	Access to charging points, commute distances	Driving range, charging duration, battery longevity

Governmental measures around electric vehicle adoption

Governmental bodies at European, national, and local levels have deployed a range of policy measures to tackle barriers to make EVs more competitive than alternatives and improve their adoption. These range from financial support and binding regulations to preferential vehicle access.

Fit for 55 package [17]

The EU has set a binding target of climate neutrality for 2050 as part of the European Green Deal. It has also committed to cutting emissions by at least 55% by 2030 as an intermediary step. To actualize these plans, a set of proposals to revise and update climate, energy, and transport-related legislation have been put forward. This includes a revision of CO2 emission performance standards for new passenger cars and vans.

Urban policy areas [21, 22]

Cities have identified various ways to accelerate EV uptake, targeting barriers from convenience to affordability. Policy areas include improving:

- Access through low-emission zones and priority lanes
- Affordability through purchase incentives and tax benefits
- Awareness through campaigns and information centers
- Convenience through discounted congestion charging, parking benefits, and charging benefits
- Fleet electrification through procurement and requirements

Revision of CO2 emission standards [17, 18, 19, 20]

In June 2022, the Council of the EU agreed to raise and add targets for reducing CO2 emissions for new cars and vans. For cars, the targets have moved from an emission reduction from 2021 of 37.5% to 55% by 2030. A new target has also been added stipulating a **100% CO2 emissions reduction target by 2035**, meaning that ICE vehicles will no longer be sold past that point. Assuming a vehicle lifetime of 12 years, which is the EU average, the ambition of having a 100% zero-emission fleet by 2050 is more likely to come to fruition.

The Council of the EU also agreed to end the regulatory incentive mechanism for zero- and low-emission vehicles from 2030. This regulation was in place to support early market uptake by rewarding higher EV sales with lower CO2 emission reduction targets.

Uncertainties around electric vehicles

Overall, the EV market is still in its earlier stages of maturity. Several factors have the potential to threaten its growth.

Supply chain [16, 23]

Producing EVs on a mass scale requires the reorganization of the supply chain. Getting a new model produced means dealing with a complex and large assembly line – one that relies on the timely delivery of thousands of parts by component manufacturers.

Battery supply [24, 25, 26]

Some challenges arise when it comes to EV battery supply:

- Raw material availability; BloombergNEF expects lithium, nickel and cobalt demand to exceed currently known reserves. Accordingly, recovering high-value materials from batteries, which is expensive and difficult, will need to be done on a large scale, and more investments will need to go into mining and refining, new cell chemistries, and public charging infrastructure.
- Regional supply; localization is important to improve transparency and save working capital. Many giga plants will be needed – for example, Volkswagen alone expects to operate six cell factories in Europe by 2030. Currently, Europe's batteries mainly come from Poland and Hungary, and there are several large-scale battery gigafactory projects under construction.

Maintenance revenue streams [23, 27]

According to a study examining EV business models in Nordic countries, EVs have been reported by experts to incur 80-90% less post-sale maintenance expenses. While this provides value to the consumer, it potentially takes away 50% of a car dealer's revenues. While the decline of after-sales markets is more of a long-term issue, which also remains postponed so long as many PHEVs are sold, it is a pressing one that affects OEMs and car dealerships at their core and **gives them no option but to innovate and explore different ways of making profit**. To illustrate, OEMs like Nissan have experimented with using old battery packs to provide back-up power for buildings.

Hydrogen fuel cell vehicles [28, 29]

Alternative clean vehicles may become more competitive than electric vehicles. Currently, their development is focused on the freight sector where distances are longer and quick refueling is more desirable. However, prices are high and refueling infrastructure is an additional barrier.

The availability of public charging infrastructure is one of the key challenges that stand in the way of widespread EV adoption. It is needed to fulfil driving needs when there are no other private alternatives e.g., at home or at the workplace, and is essential in alleviating range anxiety and facilitating long distance travel. [30, 31, 32] The business model for provision of charging infrastructure, however, is not so clear. [33]

Trends in electric vehicle charging

A primer on charging technology

Over the years EV charging has seen drastic advancements in technology. More and more, solutions are being developed to meet the charging demands of different EV users conveniently.

Plugging in [34, 35]

Typically, EVs charge by parking and connecting to a charging point through a connector. The standard connector type used in Europe is the Type 2 connector, an AC connector which offers speeds up to 43 kW. For faster charging, CSS is commonly used, although cars such as those produced by Mitsubishi use the CHAdeMO connector which provides power much faster than what today's EVs can draw in. More and more, OEMs such as Nissan are switching to CSS.

Smart vs dumb chargers [36, 37]

Chargers come in networked and non-networked forms, distinguishing chargers into smart ones and dumb ones. The key difference is that smart chargers come with software that allows communication. This means that they can connect to the cloud and be managed remotely, allowing for energy consumption to be optimized. It also means they provide access to behavioral data.

Charger speed [30, 33]

Chargers are often classified by their speed, which is determined by a number of parameters such as output power. The categories and descriptions vary widely across literature and regions. One classification follows.

Speed	Output power	Capacity	Approximate duration
Slow	AC	≤ 10 kW	3-8 hours
Normal	AC	10-22 kW	1-2 hours
Fast	AC / DC	22-50 kW	20 minutes - 1 hour
Ultra-fast	DC	> 50 kW	10-20 minutes

More about rapid charging [9, 16, 33, 38, 39, 40, 41]

As technology progresses, the experience of ultra-fast charging will get closer to replicating the experience of refueling an ICE vehicle. The recent introduction of DC chargers that have the capacity to deliver 350 kW or even 400kW is an example of such an opportunity. They would allow BEVs to recharge approximately 320 km of driving distance in 10 minutes. Developments in rapid charging help reduce range anxiety and build confidence in EVs. They are also useful for vehicles driven for commercial purposes e.g., taxis or shared cars. However, a couple of challenges remain:

- Investment costs; ultra-fast chargers have been reported to cost more than four times the hardware and installation costs of slower chargers
- High power demand; ultra-fast chargers draw in a lot of power in a short amount of time which can negatively affect grid performance
- Battery degradation; ultra-fast charging may reduce battery life if used especially frequently and at high power levels

A primer on charging technology

Over the years EV charging has seen drastic advancements in technology. More and more, solutions are being developed to meet the charging demands of different EV users conveniently.

Wireless charging [15, 16, 42, 43, 44]

Wireless inductive charging is a concept currently being explored. It relies on a wireless connection via a magnetic field between a transmitting pad on the ground that is connected to the grid and a receiving pad at the bottom of the EV. It can be used not only while the vehicle is parked but potentially while it is on the move, as demonstrated by pilots in Sweden.

One of the most promising applications of wireless inductive charging is by commercial EVs that are looking to quickly supplement charging and extend their range. An advantage of wireless charging is that it is automated and does not require human intervention, making it suitable for autonomous driving. In addition, it is more space-efficient. However, the concept is still at an infancy stage, and currently faces several challenges such as complex upgrades, expensive infrastructure costs, and poor efficiency of energy transfer.

Charging use cases

There are different types of electric vehicle users, each with their diverse preferences and needs. From these, a few charging use profiles appear. [15, 16, 33, 45, 46, 47, 48, 49, 131]

	Home	Workplace	Fleet hub	Destination	Transport hub	Street	Highway corridor
Locations	Single dwellings Multi-unit dwellings	Workplace car park Depots	Depots	Commercial areas Social and recreational areas Public parking lots	Park and ride Railway stations Airports Mobility hubs	Dense residential areas	Highways
Users	Residents	Commuters Vehicles supporting business operations	Fleets of light commercial vehicles and heavy-duty vehicles	Variety including visitors, commuters, and vehicles supporting business operations	Variety including commuters, shared vehicles, taxis, public transport vehicles, short-stay pick-up/drop-offs	Variety including shared vehicles and residents	Variety including private and commercial vehicles travelling long-distance
Time of day	Mainly overnight*	Daytime	Overnight	Mixed	Mixed	Mixed	Mixed
Speed	Slow	Slow	Fast	Variety	Variety	Variety	Rapid
Value propositions	Cost-effective, reliable and convenient charging Fulfils average daily travel needs	Alternative to home charging that is often free Integrates more solar energy	Facilities for last-mile logistics Unmanned overnight vehicle parking	Opportunity to combine charging with other activity and top up Drives commercial activity	Alternative to workplace charging Promoting multi-modal mobility and last mile options	"Homeless fleet" charging Reduces range anxiety On-the-go charging	Extends range necessary for interregional travel Similar experience to refueling
Challenges	"Homeless fleets", especially in apartment buildings where it is difficult to individualize electricity consumption and declines in requests to install chargers from housing associations are frequent	May add to peak demand, depending on type of business	Considerable investments needed if installing high-power charging	Not usually accessible outside of opening hours Unpredictable charging profile	Complexity in planning	Adequate coverage Public space	High upfront costs High impact on grid with limited opportunity for smart charging

* While home charging is frequently associated with overnight charging, it is not necessarily the rule. Whether a person charges their car overnight could be determined by whether it is the weekend or weekday, whether they have flexible working hours, and to what extent they use their car.

Trends in the provision and use of charging infrastructure

We see several trends emerging around the use of charging infrastructure.

Moving towards public charging infrastructure [16, 33, 48, 50, 51]

There are three broad typologies of charging infrastructure: ones with private access, limited public access i.e., for a certain group of people or constrained by opening hours, and, finally, ones with full public access. More so, private charging points are being opened up for public use and **"integrated into the community"**. This is being done by public organizations like schools or local council offices, as well as private companies such as Clem, a carsharing company in France, which allows private EV users to book their chargers. In addition, sharing economy platforms such as ElBnB which connects homeowners to members of the public are emerging.

Popularity of use cases [15]

Charging at home is currently the most common use case, followed by workplace charging. With the growth of the EV fleet, EY analysts expect that this trend continues, estimating that in 2035 85% of charging will be done at home and 6% in the workplace. When it comes to the division between semi-public (destination) charging points and on-street/highway charging, analysts and experts expect a large role for the former, estimating that 5% of charging will be done at semi-public (destination) charging points, and 4% on-street and on highways.

Differences between refueling and charging behavior [45, 52, 53, 54, 55]

Both EV and ICE vehicle drivers are tasked with ensuring that they have enough power and range to execute their preferred travel behaviors. However, one needs to be careful not to assume refueling behaviors can be translated one-to-one to charging behaviors. For one, the user groups differ in sociodemographic characteristics such as income. Second, they deal with vastly different infrastructure networks; gasoline and diesel drivers have the luxury of countless stations to choose from which means that they do not have to plan ahead and that they can afford to be picky about factors like price.

One pattern that has been reported among EV users is that they tend to recharge the quantities they consume immediately in a timely manner whereas ICE users often run on empty and then refill the tank completely. EV users have been reported to **charge their vehicles like they do their smartphones**, topping up as they go, when the opportunity arises, despite substantial battery life. Behavioral differences are suggested to level out as charging infrastructure availability and speed develop and come closer to replicating the fueling experience, and as range anxiety decreases. **This raises questions on the proliferation and use of on-street and highway charging.** However, as is discussed in further sections, we expect these use cases to be only **complementary** to more dominant use cases of home, workplace, and destination charging.

The energy impacts of EV charging

Along with the growth in EV adoption and use comes a greater demand for electricity to fulfil charging needs. To illustrate, the International Energy Agency expects the share of European electricity consumption attributable to EVs to grow from 0.3% in 2020 to 3-5% in 2030. [25]

Impacts on electricity demand [1, 15, 49, 56]

According to Eurelectric and EY, **the grid can handle the rise in demand**. The real bottlenecks come when we consider demand on a day-to-day basis – when thousands or millions of EVs charge at the same time, not to mention during already **strained peak hours or in heavily loaded grids** that are mostly equipped to handle items like household appliances. The increase in peak demand and congestion of the local distribution network puts the operation, security, and quality of power supply at great risk, especially considering that disruptions are more likely in the case of the **irregular generation of renewable energy, which is growing**.

Renewable energy integration [15, 27, 49, 56, 61]

As long as their batteries are supplied by electricity that comes from fossil fuels, BEVs will not be carbon neutral. **Electrification goes hand in hand with the decarbonization of the power sector.**

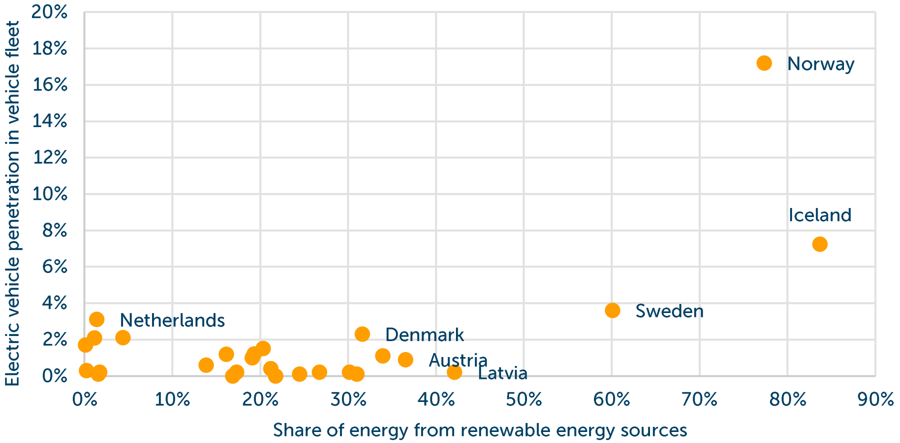
The main challenge of integrating more renewable energy into the energy supply mix is **matching its intermittent availability with electricity demand** – at the grid level as well as for distributed energy generation. Regions with dominantly wind power generation benefit from it being quite well matched with unmanaged charging behavior – wind blows more so in the evening, when vehicles are charging overnight, although predictability is an issue. On the other hand, regions that are high in solar power generation struggle with unmanaged charging – solar power is generated during the day, when people don't usually charge their vehicles. Accordingly, solutions to manage charging may provide greater benefits for solar-based systems. Storage technologies are also helpful.

Impacts on grid infrastructure [15, 27, 49, 56]

EV charging is said to make up only 8% of total grid investment needs, coinciding with the digitization of the grid, the electrification of industry, and other emerging investment areas. Nevertheless, the scope of investment will differ from location to location based on:

- Congestion and capacity
- Simultaneity factor i.e., the probability that pieces of equipment are switched on at the same time
- Load characteristics e.g., areas with high shares of electric heating might have a higher load curve during winter than if heating were done through gas
- Degree of power generation at the low voltage level
- Grid code limits and other regulations

Decarbonization and electrification by country (2020)
Source: European Environment Agency [60]



By 2030, 85% of EU electricity will be carbon-neutral across different sectors, the majority coming from renewable energy sources. [62]

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Examples of grid infrastructure impacts geographically [15, 27, 57, 58, 59]

The impact on the grid differs geographically. For example, the capacity of the Dutch grid has been built to meet a peak demand that can easily charge 1.9 million electric vehicles by 2030. In France and Norway, electricity has powered heating for a long time, and grid investment costs related to electrification make up approximately 1% of capital expenditure. The same is to be said for Finland where the use of electricity for heating and saunas is common practice and detached houses are often equipped with fuses that provide sufficient capacity.

On the other hand, in Hamburg, a DSO found that a 9% EV share would produce bottlenecks in 15% of the network's feeders. Reinforcement would translate to at least 20 million euros. Furthermore, **Eastern Europe is lagging behind with an underinvestment in grid infrastructure**. Due to lower affordability, households are charged lower electricity tariffs that usually do not cover costs and thus produce grid unreliability. Households also consume less electricity per day on average; in some cases, a full recharge of an EV would consume thrice the average daily electricity consumption.

Examples of grid infrastructure impacts by charging profiles [15]

The impact on the grid will depend on the charging use case. According to Eurelectric and EY, the impact on peak demand is largest where there is a coincidence in usage patterns, like with residential urban charging. Furthermore, higher charging speeds mean greater impact; the use of a single ultra-fast charger can increase peak load by up to 90%, beyond manageable limits, compared to multiple slow chargers in a home or workplace use case.

Protecting the grid means more than adding capacity – it means enabling EVs to act as assets to the energy system and optimize it, benefiting all users. Smart charging is one way to do this. [9, 55, 56, 61]

EVs as assets [15, 27, 55, 56, 61]

The traditional solution to grid capacity issues is to add capacity and pass on costs. However, EVs, like other appliances being connected to the grid, have the flexibility to manage their demand i.e., to change when and how much they consume electricity. **The ability to balance demand and supply shifts EVs from a liability to an asset which helps integrate more renewables into the power supply mix, reduce the need for grid reinforcement, and provide cost savings for all.** Several technologies enable this, the most discussed being **smart charging**.

Smart charging for flexibility

Protecting the grid means more than adding capacity – it means enabling EVs to act as assets to the energy system and optimize it, benefiting all users. Smart charging is one way to do this. [9, 55, 56, 61]

Types of smart charging technologies [15, 27, 49, 61, 63]

Time-of-use pricing	Unidirectional controlled charging (V1G)	Bidirectional controlled charging (V2G/V2B)
A price signal encourages consumers to voluntarily deter charging to cheaper periods of time. This helps avoid peaks in energy demand and limits the need for grid reinforcement.	The time, rate, and duration of charging responds to activation requests or dynamic price signals. This helps flatten peak demand, fill load values, and support real-time balancing for DSOs.	The time, rate, and duration of charging responds to activation requests or dynamic price signals. Crucially, the vehicle can also supply energy back to the grid or building, so it can provide additional services: V2G provides benefits of V1G in addition to ancillary services (primary, secondary or tertiary reserve products differing in reaction time) for TSOs. It also supports the integration of more renewable energy when its supply is high. V2B provides backup power; it can provide enough electricity to a home for several days while still being used for daily travel. It also optimizes a building's energy by lowering peak demand, providing power and energy cost savings.

More about time-of-use pricing [61, 63]

There are different types of electricity tariffs that can be utilized by EV users directly or by third-party aggregators of private or public charging points. This includes:

- Static; pricing is based on large time blocks of several hours e.g., day and night pricing. This is predictable and straightforward, but limits cost savings and grid benefits. Eastern Europe lags behind with countries like Poland and Hungary not offering a single time-of-use tariff.
- Dynamic; pricing is based on close to real-time consumption of electricity and wholesale prices e.g., hourly or 15-minute pricing. This means prices can fluctuate greatly, even becoming negative if not capped, offering more potential for cost savings at greater risk. This is mainstream in Scandinavia and Spain, and is emerging in the UK, Netherlands, Austria and Italy.

Tariffs can be responded to automatically, which is especially helpful the more advanced the pricing is. **Provided there is control over the charging process, information about the battery, vehicle, minimum desirable state of charge, and preferred departure time can be used to optimize charging and reduce electricity costs.**

More about controlled charging [27, 49, 63]

Several technical, economic, and social challenges stand in the way of managed charging, especially surrounding V2G/V2B technologies which are still in testing compared to V1G which has already been deployed in some markets:

- Communication protocols and data security
- Consumer acceptance and trust
- Concerns of battery degradation
- Double taxation
- Profitability

Smart charging for flexibility

Several broader implications appear when it comes to smart charging.

The added value of parking [27, 56]

Generally, cars are said to be parked for about 95% of their lifetime. Charging has allowed for more efficient use of that time. The International Renewable Energy Agency estimates that the time needed for an EV to charge enough so that it can meet its yearly electricity needs makes up 10% of the time it is parked. Assuming the duration of charging equals the duration of parking i.e., that there is no charging hogging, there remains 85% of the time where the vehicle is nothing but parked. That 85% represents an opportunity for smart charging to be used to provide flexibility services, to the grid or otherwise.

With smart charging, there is value in idle time so long as the vehicle is plugged in. This value increases with longer continuous connection times and less and more predictable vehicle use. Should wireless charging technology become standard in the next decades, the vehicle will not even have to be plugged in for smart charging to occur. One could argue that the penetration of smart charging will have consequences on the nature of parking, and accordingly, what it means to provide and operate parking spaces.

Charging hogging [27, 56]

The longer a vehicle remains connected to a charging point, the longer it can serve the grid and save costs. However, while a vehicle is connected to a charging point, the charging point cannot be used by others, resulting in potential opportunity costs should the lost revenue from a missed charging session outweigh the costs saved on electricity. Accordingly, smart charging is arguably most convenient in cases where the average duration of charging is already long.

Vehicle ownership [56, 61, 64, 65]

Smart charging might reduce the cost of vehicle ownership for consumers, potentially incentivizing more vehicle kilometers travelled. Furthermore, **smart charging expands the value proposition of owning a car** – no longer is a car just a means of transportation, it is a safety net and a way to optimize one's energy consumption. You can rely on it to supply your home with power during outages, or you can use it to store cheaper renewable energy for later use. OEMs like Volkswagen and Ford have marketed benefits like these to consumers, although it is likely that they resonate with rural consumers more so than city dwellers. This may shift the context of urban mobility policy.

Energy storage

Energy storage acts as an alternative to smart charging, helping increase the use of renewable energy and postpone grid reinforcement. As renewable energy supply increases from both centralized and distributed sources, storage can be used to smooth out fluctuations in supply with minimal loss. [15, 27, 49]

Storage technologies in buildings [49]

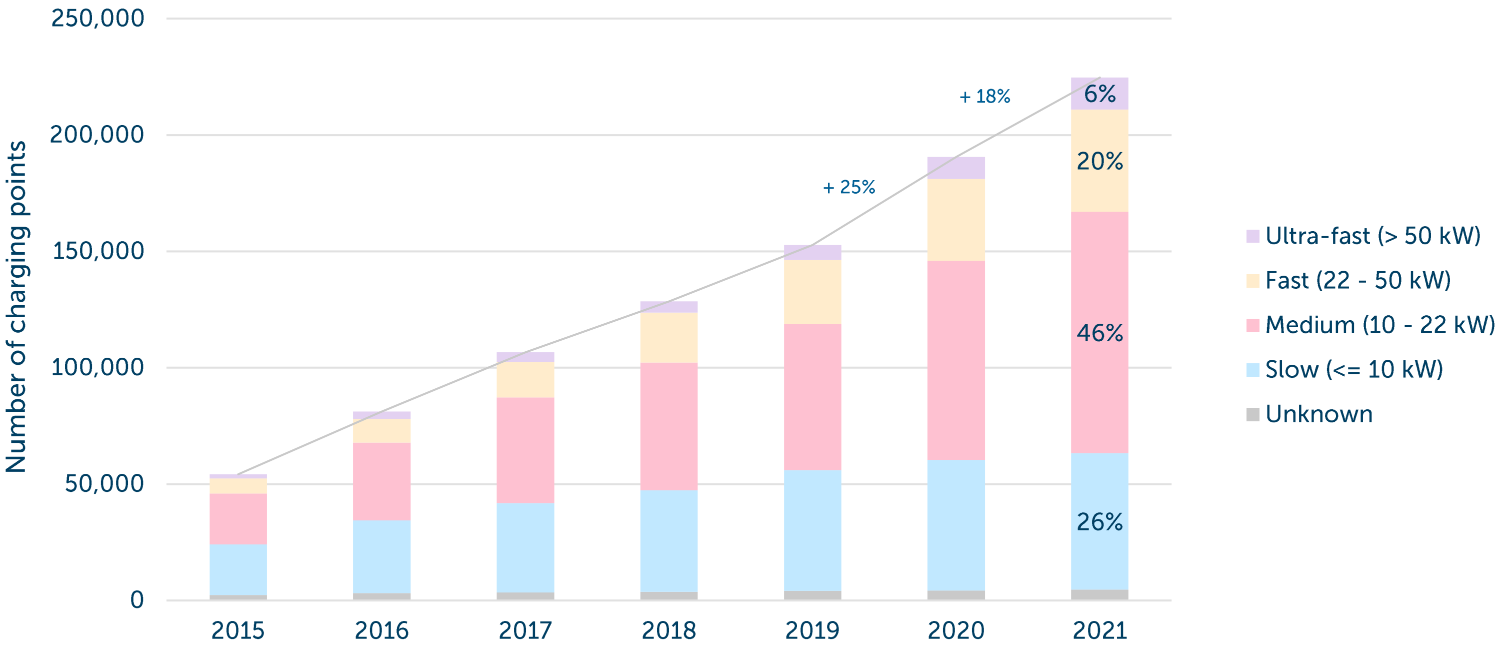
Storage technologies are interesting to discuss in the context of buildings. If they are coupled with local energy generation, buildings can take control of their energy supply, create cost savings, and improve their independence from the grid. If building energy management systems are used to improve energy efficiency, EV charging can be optimized according to the electricity consumption of other appliances.

Rollout of public charging infrastructure

Stock of public charging points

To understand the development of public charging infrastructure* in Europe, we first take a look at its evolution over time.

Stock of chargers in Europe over time, categorized by speed



Source: Open Charge Map [66]

Over the years the stock of public charging points has grown dramatically. In 2021, more than 220,000 charging points were recorded – 177% more than was recorded five years prior. Most of these charging points were medium and slow speed, followed by fast and ultra-fast.

* We limit our analysis in this section to charging points that are accessible to the public, whether they are fully accessible or are limited by certain conditions such as opening hours or types of users. For more information on the scope of the analysis and the sources and reliability of the data, please refer to the appendix.

Stock of public charging points

We now examine several basic metrics which reveal the distribution of charging points between European countries. This helps understand to what extent variations in the concentration of charging infrastructure exist.

79% of Europe's public charging points are concentrated in just five countries.

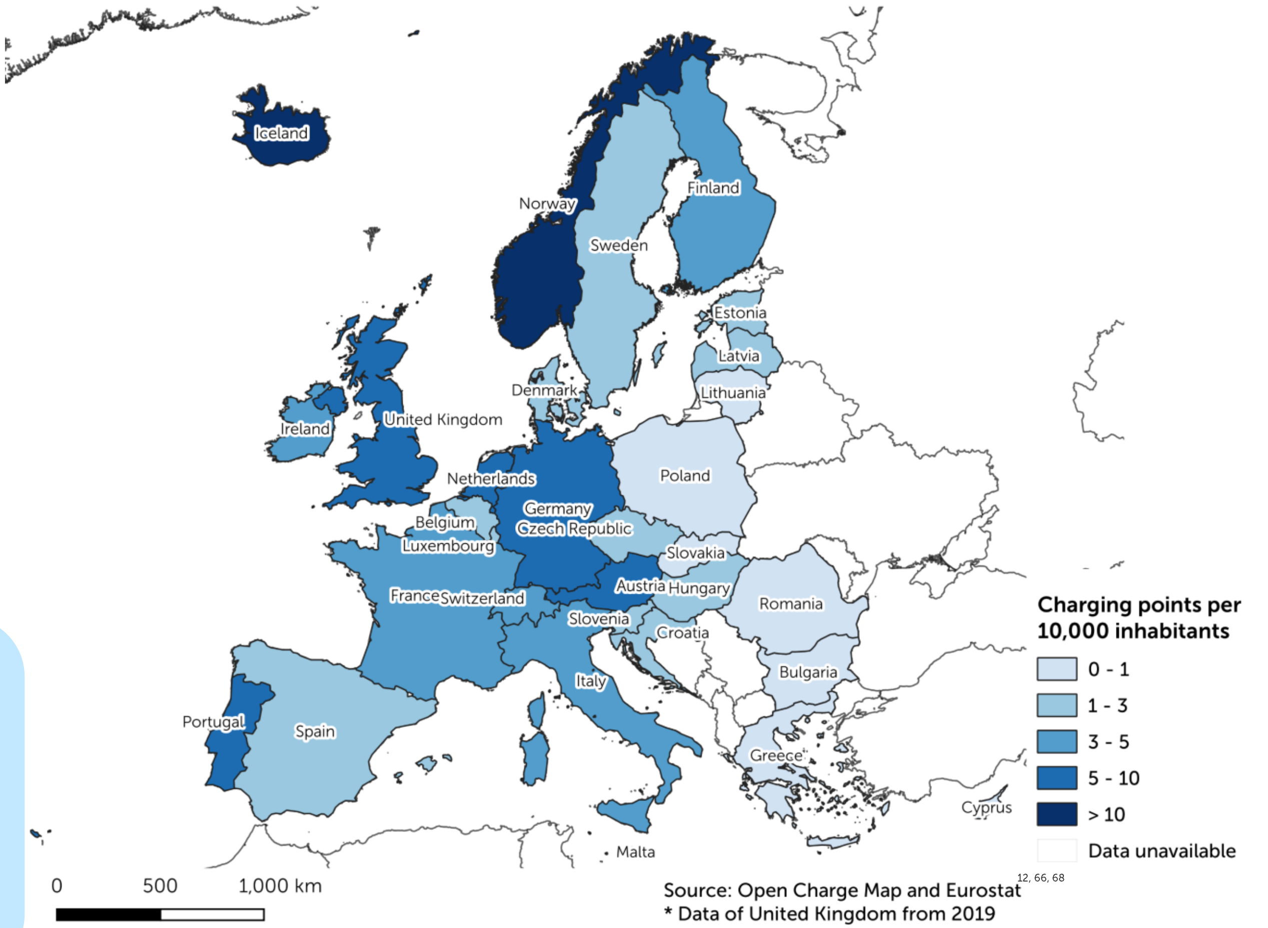
Distribution of charging points in Europe (2021)

Source: Open Charge Map [66]

Adjusting the number of charging points for each country's population size, we see quite some variance between countries. Whereas Iceland and Norway have almost 14 charging points per 10,000 inhabitants – outliers compared to the European average of 4 – countries like Bulgaria, Cyprus, and Lithuania have less than 1 charging point per 10,000 inhabitants.

The geographic divide is also reflected when examining the ratio between charging points and kilometers of road. Eight countries, all Eastern European, have not even one charging point per 100 km compared to the Netherlands, which is on the upper end of the spectrum and has 12. [66, 69, 70]

Ratio of charging points (2021) to population (2020)*

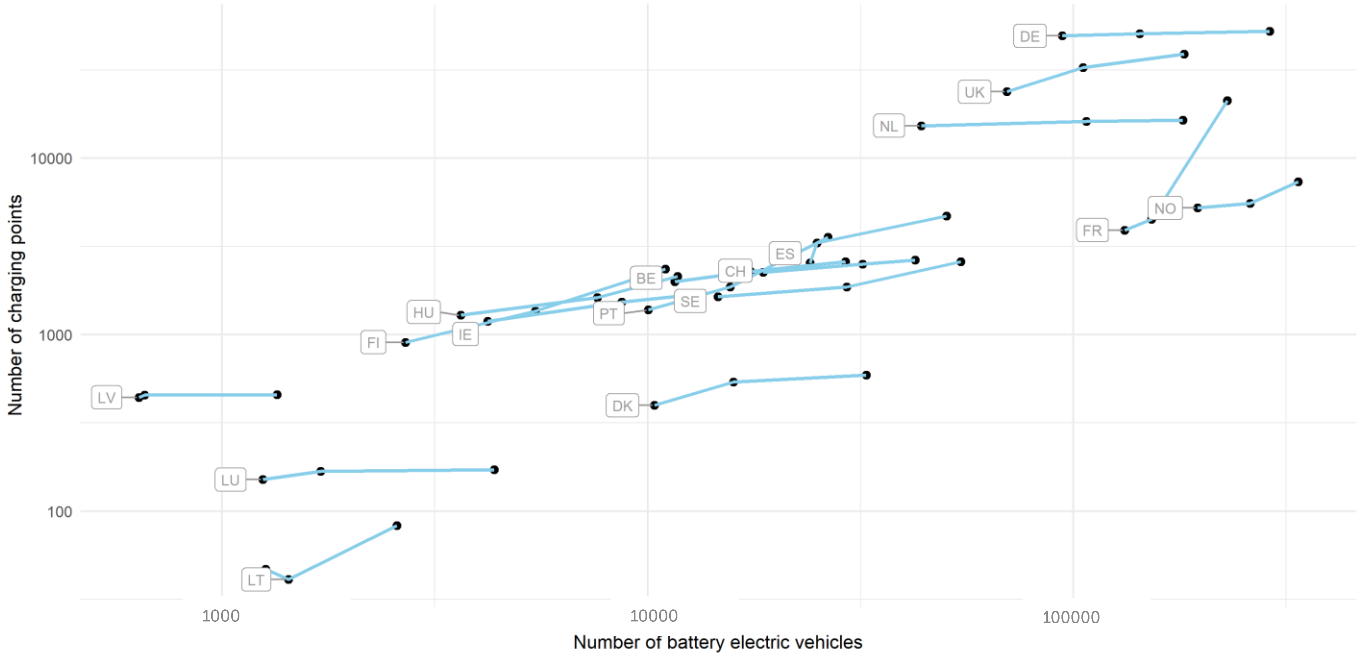


Source: Open Charge Map and Eurostat [12, 66, 68]
* Data of United Kingdom from 2019

Stock of public charging points

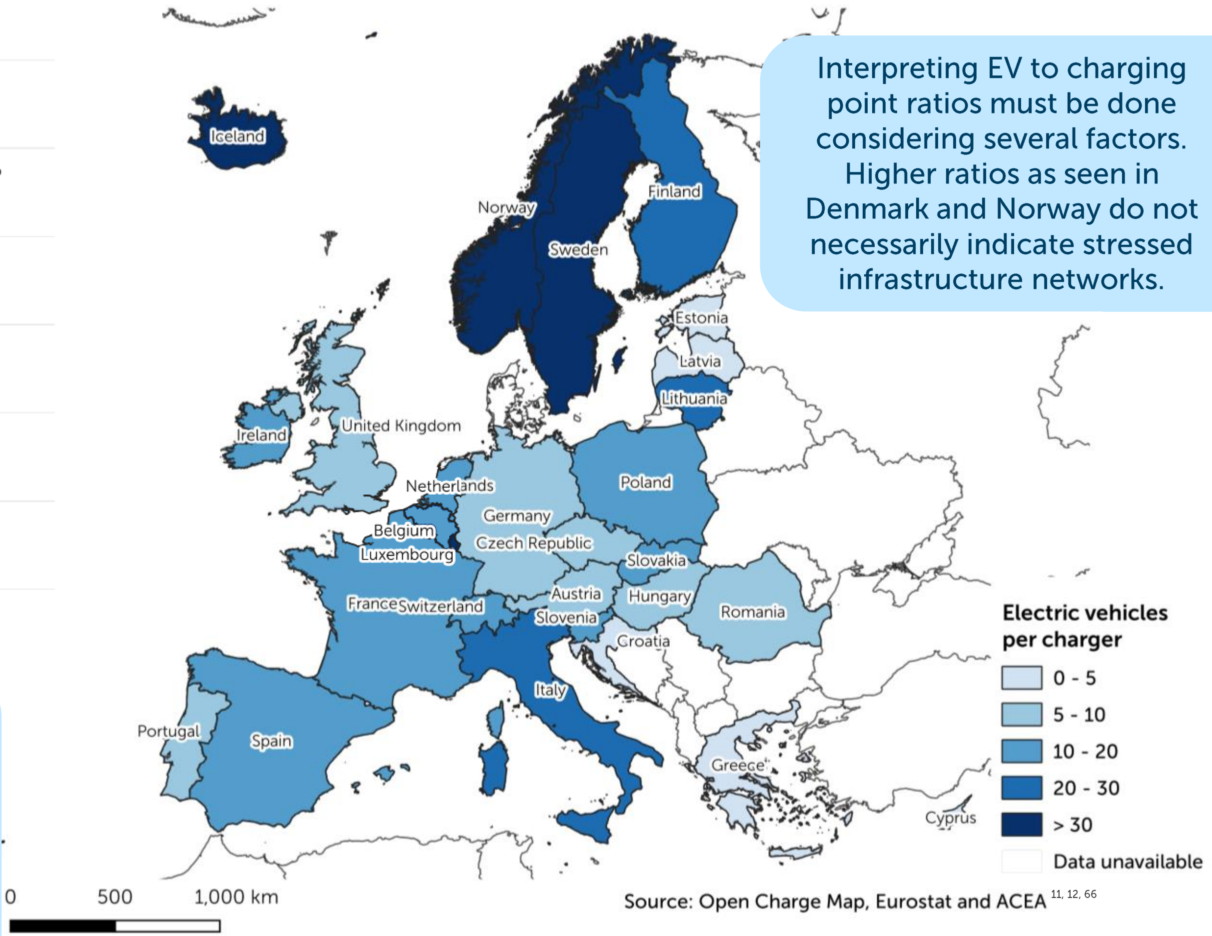
How much charging infrastructure is needed will greatly depend on the size of the EV passenger fleet. Comparing these two figures to one another helps further understand where gaps in charging density lie.

Development of BEV stock and EV charging points (2018-2020) [11, 66, 71, 72]



Plotting the number of charging points against the stock of battery electric vehicles over the years (in logarithmic scale to compare countries of different size) allows us to see the evolution in their relationship. In the figure above most lines become flatter, meaning that at the beginning the increase in charging points exceeds the increase in BEVs, followed by the opposite. This suggests a. a positive association between charging infrastructure and BEV adoption and b. that networks are becoming more efficient over time, approaching an equilibrium. That being said, in advanced EV markets, one questions the sufficiency of charging infrastructure given the rise of V2G and its associated connection times. [30, 104]

Ratio of electric vehicles (2020) to charging points (2021)

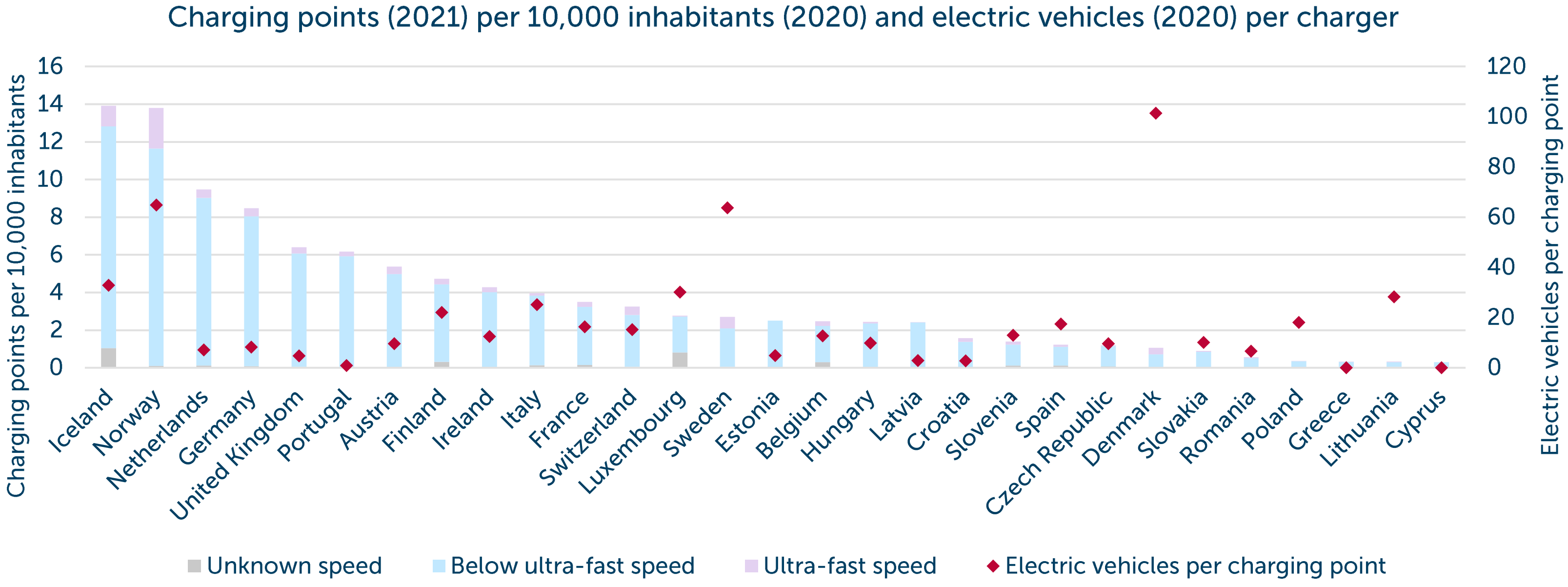


Source: Open Charge Map, Eurostat and ACEA [11, 12, 66]

Interpreting EV to charging point ratios must be done considering several factors. Higher ratios as seen in Denmark and Norway do not necessarily indicate stressed infrastructure networks.

Stock of public charging points

How much charging infrastructure is needed will greatly depend on the size of the EV passenger fleet. Comparing these two figures to one another helps further understand where gaps in charging density lie.



Source: Open Charge Map, ACEA, Eurostat [11, 66, 68]

Contextualizing EV to charger ratios

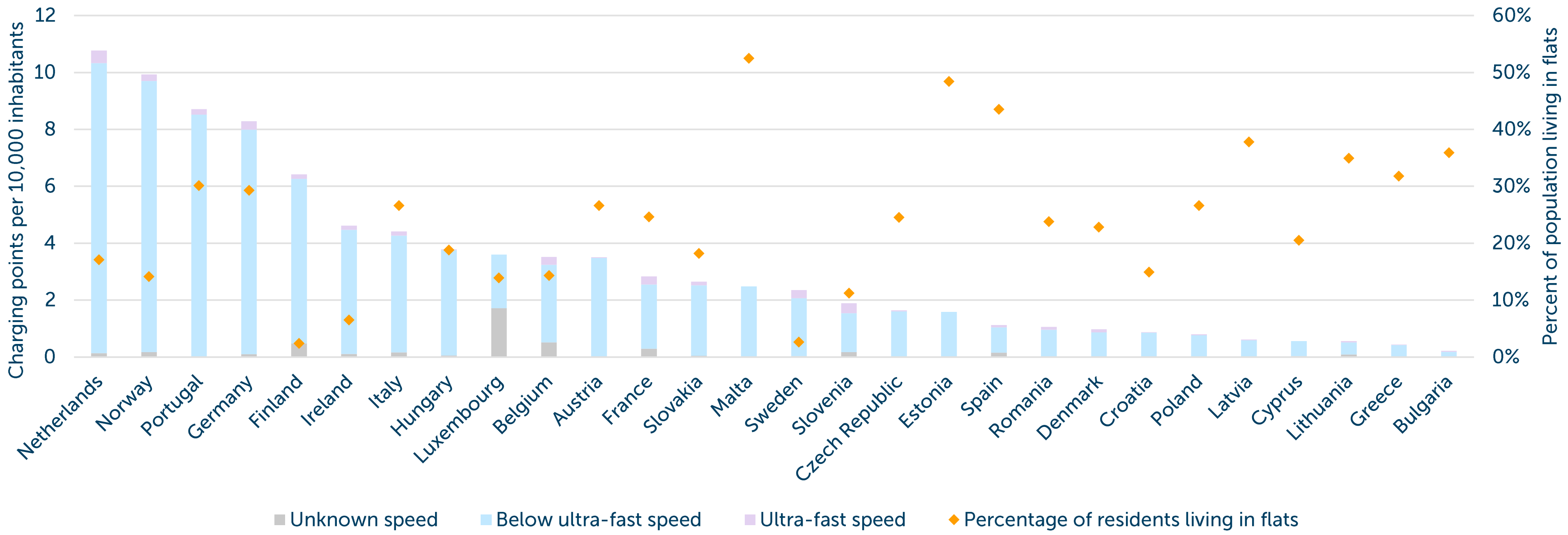
Consider a country like Norway. It has the second-highest EV to charger share, which paints the picture of an overloaded network of charging infrastructure especially when considering it is more than 3 times the EU guideline of 10 EVs per charger. However, Norway has:

- The highest EV share of Europe at 17%; it benefits from the addition of one charger less so than countries in, say, Eastern Europe [11]
- The 4th highest share of ultra-fast chargers at 16%; it is able to satisfy power needs with a lower number of charging points than countries with a low share [66]
- The 6th lowest share of inhabitants living in flats at 23%; this means that the majority of inhabitants most likely have access to private charging with their detached or semi-detached houses [133]

Stock of public charging points

Analyzing national-level figures present only a limited picture. Local factors such as housing stock and population density can create differences in charging needs and charging infrastructure network development.

Charging points (2021) per 10,000 inhabitants (2020) and share of population living in flats in densely populated areas of European countries (2020)



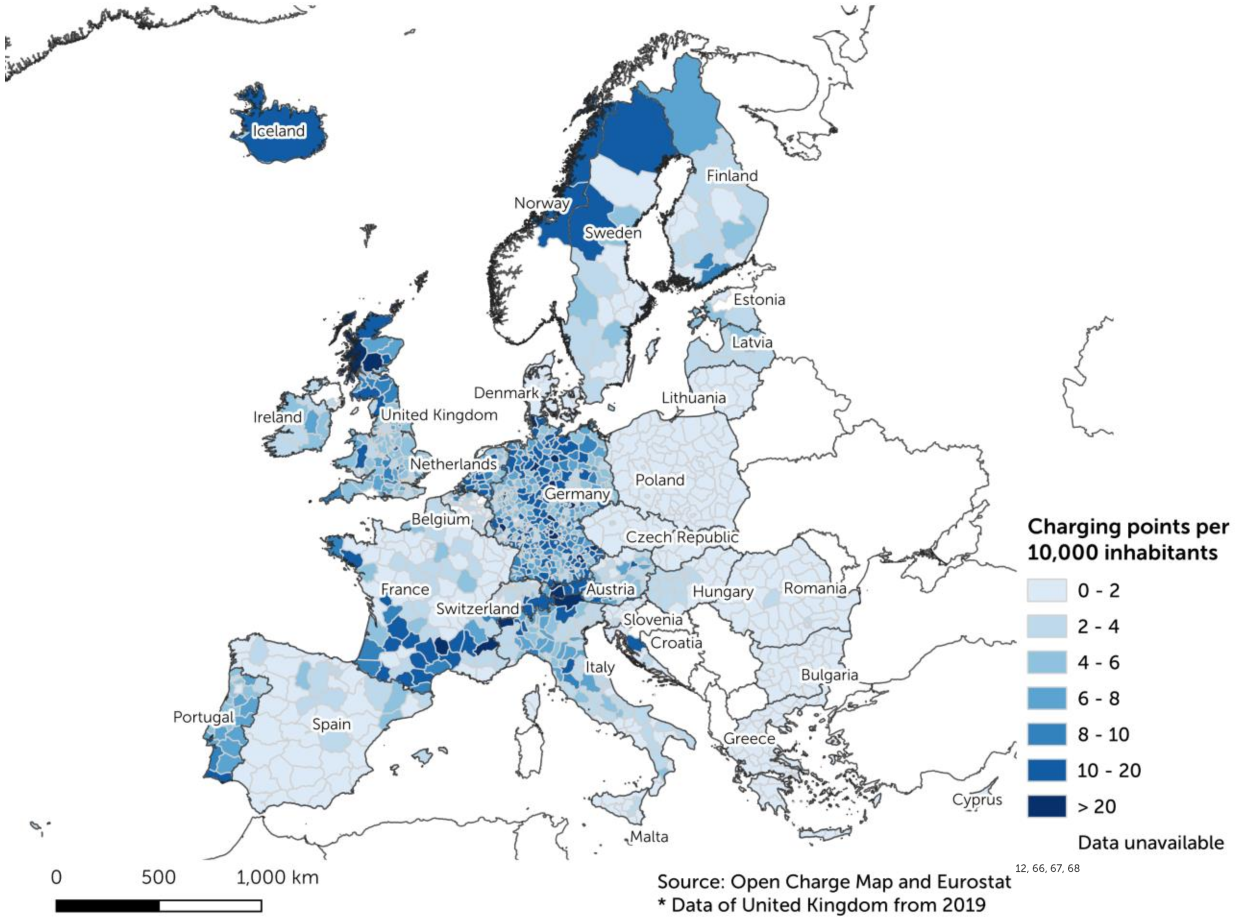
Source: Open Charge Map, Eurostat[66, 133, 134]

The above figure takes into account only densely populated areas (cities) of countries across Europe and plots the concentration of charging points per population against the percent of city population living in flats. What we can see is that cities like Malta, Estonia, Spain, and Latvia have a limited deployment of public charging infrastructure, possibly due to low EV adoption, yet tend to be on the higher end of the spectrum when it comes to population living in flats. This suggests that these countries' cities will need to put significant effort into ensuring that people without access to private garages have access to affordable alternatives.

Stock of public charging points

Analyzing national-level figures present only a limited picture. Local factors such as housing stock and population density can create differences in charging needs and charging infrastructure network development.

Ratio of charging points (2021) to population (2020)* by NUTS-3 region



Source: Open Charge Map and Eurostat [12, 66, 67, 68]
* Data of United Kingdom from 2019

We find that there is not a strong difference between urban and rural roll-outs of public charging infrastructure. Predominantly rural areas in Europe see 5.4 charging points per 10,000 inhabitants compared to 5.1 in urban areas. This may be explained by similarities in EV uptake between urban and rural regions. [12, 66, 67, 68]

The public charging experience

The experience of charging an EV is defined by much more than the concentration of charging points in the area. Issues like the standardization, pricing, reliability, and availability of chargers are barriers that can limit the utilization of charging infrastructure networks, directly or indirectly by inhibiting EV adoption.

Standardization [34, 79]

EV charging infrastructure has in most cases had a relatively haphazard rollout due to the fragmentation of the market. With so many actors, their varying degrees of involvement and expectations, and a lack of a shared vision, there is little standardization. As adoption grows and more people rely on public charging, this becomes especially relevant to address.

Identification and billing [34, 79, 81, 82, 83, 84]

For EV drivers to charge their car at any publicly accessible charging station, there needs to be a standardized system for stations to identify them, verify them, and potentially secure payment. For this to occur, back offices of CPOs need to be connected, and usage data and payment information consolidated and transferred according to open standards.

Several national- and local-level interoperability initiatives exist in Europe. Having achieved nationwide interoperability since 2011, the Netherlands is by far a leader compared to other countries. ELaadNL, a consortium of grid operators, and many other parties like mobility providers helped push the widespread adoption of open standards such as the Open Charge Point Protocol and the Open Smart Charging Protocol which allows efficient communication between charging stations, the grid, and back-end offices. All public tenders mandate the enforcement of these standards, and now drivers can reliably charge their car at any public charging point through an RFID card or key fob. There are some examples of city-level interoperability, like the case of Stockholm where charging points installed as part of the city's plan must be interoperable.

Plug types [34, 80]

The discrepancy in plug types appears with DC fast charging connector types. In 2011, the Charge de Move fast charging standard was created, used by Nissan, Mitsubishi, Kia, Citroën, and Peugeot. However, car manufacturers like BMW, Daimler, Ford, Volkswagen, Hyundai, Fiat Chrysler, General Motors and Honda use the more widely adopted Combined Charging System. Although some vehicle manufacturers like Nissan are making a switch and using CSS sockets in their new models in Europe, it will take time before the vehicle fleet is turned over and CHAdeMO plug types will not be needed anymore.

The public charging experience

The experience of charging an EV is defined by much more than the concentration of charging points in the area. Issues like the standardization, pricing, reliability, and availability of chargers are barriers that can limit the utilization of charging infrastructure networks, directly or indirectly by inhibiting EV adoption.

Pricing [16, 33, 61, 77, 78]

Pricing for charging is not as straightforward or transparent as pricing for the refuel of an ICE vehicle. It is not standardized, as evidenced by the ability to pay by duration, by kWh, etc. This makes it difficult for the EV user to compare different charging options. There is also a discrepancy between the price/kWh of private and public charging – for reference, in the US, private home charging was found to be 2-3 times cheaper in 2020, and a study by the UK National Audit Office reported private charging at home to be 59-78% cheaper. This raises the question of the severity of an **affordability gap between those who have access to private home charging and those who do not** and must rely entirely on public charging.

Reliability of charging point data [16, 132]

Finding reliable information about public and semi-public charging points can be a challenge for consumers. Charging points often go unlisted, and if they are listed can have wrong or outdated data around access information, charging speeds, and parking and accessibility restrictions. This can reduce consumer confidence and reinforce range anxiety.

The public charging experience

The experience of charging an EV is defined by much more than the concentration of charging points in the area. Issues like the standardization, pricing, reliability, and availability of chargers are barriers that can limit the utilization of charging infrastructure networks, directly or indirectly by inhibiting EV adoption.

Charging hogging [86, 87]

You need to park your electric vehicle for it to charge, and you may opt to charge your electric vehicle as it is parked. **This overlap between the demand for charging and parking can produce charging hogging i.e., longer than optimal occupancy of charging infrastructure**. Several factors drive charging hogging:

- Normal parking behavior; leaving your vehicle idle overnight, on weekends, or on holidays.
- Parking pressure; this is especially the case in large cities where it is more severe. It can make it so that EV or ICE drivers park their vehicles at charging points without charging.
- Type of user; for example, a carsharing vehicle has unpredictable use and may be parked at a charging spot for a while until the vehicle is matched with a customer.
- Policy; attempts to increase EV uptake by providing parking benefits can lead to unintended consequences.

The unintended results of EV parking benefits [88, 89, 90, 91, 92]

A 2018 Dutch study compared charging behavior between Utrecht, a city that provided free parking for EVs in parking areas that were otherwise paid, and other large cities without these parking benefits. It found that connection times of EVs were significantly longer in Utrecht's paid parking areas than in the paid parking areas of other cities where EVs were not exempt.

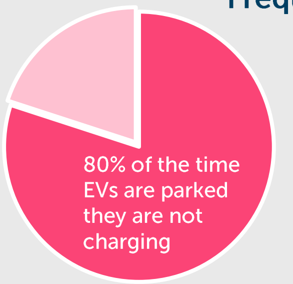
EV parking benefits can come in the form of discounted parking, like a 50% discount in Helsinki for street parking, or even free parking, like in Oslo where BEV drivers could park for free in public parking lots from 2018 to 2020, or in some boroughs of London where EVs get free parking permits.

Combating charging hogging [87, 93, 94]

Idle fees, rewards, connecting users, and valet charging can help reduce charging hogging. Early experiments show that reductions in grid connection costs trump personnel fees in the case of valet charging, which is most applicable in closed environments like parking garages.

Re-examining existing pricing models is important too; according to a 2017 study, per-session fees induce longer use of fast chargers. In contrast, Tesla uses idle fees to prevent hogging of their Superchargers.

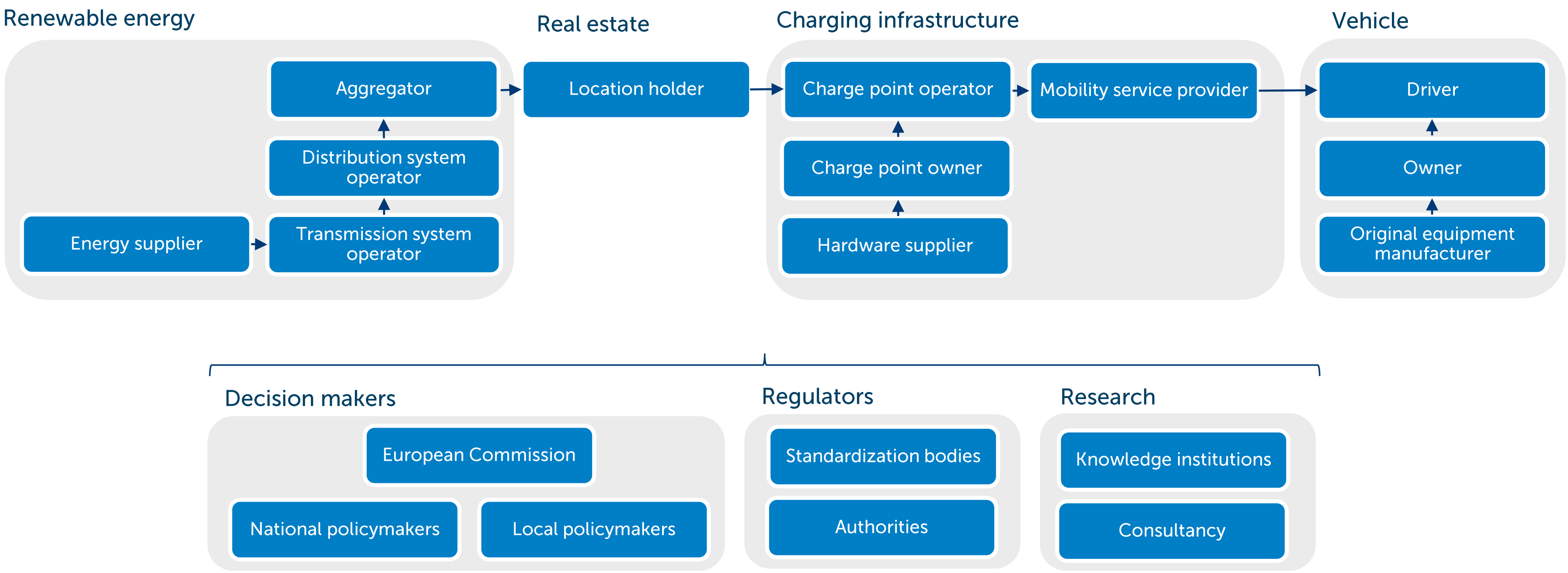
Frequency of charging hogging [85]



A study based in the Netherlands examining data from more than 1 million Level 2 public charging sessions showed that, on average, EVs charge only 20% of the time they are parked, with BEVs being left longer than PHEVs. The same study found that hogging occurred from 0% to 80% of stations.

Public EV charging value chain

The rollout of EV charging infrastructure concerns multiple groups of actors across sectors of mobility, energy, and real estate who can take up multiple roles in the value chain depending on their business model. The diagram below is a simplification of the value chain which is by no means extensive and is constantly evolving. [48, 49, 73, 74]



Public EV charging value chain

Some market roles are especially worthy to highlight since they are only just appearing, being redefined, or seeing the involvement of different actors.

Charge point operators [33, 49, 75]

The CPO is the one responsible for the day-to-day operation of charging points; they are on the customer-facing side, setting payment structures and prices, selling energy to the EV user, and gathering real-time information. Some CPOs install and own their own chargers.

The main interest of the CPO is to optimize the operation and use of the charging point. They can do so through various tactics, whether that be by ensuring interoperability with different mobility service providers, or by employing smart charging technologies at the benefit of a building or grid and, in that sense, taking part in the role of an aggregator.

E-mobility service providers [33, 49, 75]

E-MSPs are the go-to for services related to EV charging; they ensure that their customers can locate and use charging points that they have agreements with, and they provide billing services.

To broaden their customers' access to charging points across Europe, E-MSPs are increasingly collaborating with roaming platforms which act as intermediaries between CPOs and E-MSPs and ensure data transfers between the two.

* In the context of e-mobility, this term is not to be confused with organizations providing transport services like car-sharing or ride-hailing companies that use EVs

Breaking into charge point operation and ownership [30, 33, 49, 74, 75, 76]

Many major players are involved in owning and operating charging points, such as:

- Utilities companies; they have the capacity, know-how and resources to invest in charging while the market is at early stages and capital recovery timelines are long, but this may reduce competition. For reference, RWE owned more than 2800 charging stations across Germany and other countries in 2017, and it has been suggested that there are oligopolistic tendencies in parts of Germany, the Netherlands, France, and Belgium.
- OEMs; Tesla is rolling out a proprietary network of Superchargers on major European highways, which it owns and operates. On the other hand, joint ventures are being created, such as the Ionity consortium of BMW, Daimler, Ford, and Volkswagen, which aims to build a high-power charging network for electric vehicles along major highways in Europe. Since 2017, they have installed and operated more than 400 charging stations.
- Oil and gas companies; they are looking for synergies between gas stations and charging, experimenting with new business models and acquiring CPOs, like is the case with ENGIE and Shell.

Public EV charging value chain

Some market roles are especially worthy to highlight since they are only just appearing, being redefined, or seeing the involvement of different actors.

Active consumers as energy suppliers [27, 49]

The standard practice is that energy is generated and supplied by power companies, which is then facilitated at different voltage levels through DSOs and TSOs, which have the task of providing a sufficient network and preventing overload. However, more than ever are we seeing distributed energy generation where individuals and businesses generate renewable energy out of their homes and buildings. Local energy generation gives these active consumers demand flexibility, which is to the benefit of the grid. By relying on their own energy, they decrease load on the grid, and by injecting electricity into the grid, they improve the share of renewable electricity in the broader system.

Aggregators [27, 49, 63]

In the context of EV charging, the role of the aggregator is to gather energy flexibility from a fleet of EVs and offer it to the wholesale electricity market, TSO, or DSO. Essentially, they empower EV owners to make their batteries available for smart charging services, likely through CPOs, and in that sense act as an intermediary. Responsibilities include gathering close-to-real time consumption data, predicting future capacity, scheduling and activating controlled charging in coordination with energy system needs, and compensating EV owners.

The role of the aggregator in the context of EV charging is in its early maturity. Some trials have been done with charging management software which combines user preferences, car data, and information from the charging point to provide continuous forecasts to TSOs. Other business models based on smart buildings aggregating flexibility from occupants are also emerging.

Governmental measures for public charging infrastructure

Recognizing the role of public charging infrastructure in supporting the maturity of the EV market, governmental bodies at European, national, and local levels have deployed a range of policy measures to tackle barriers to the development of public charging networks. These range from financial support, direct investments, and supportive regulations to target-setting and streamlining planning and implementation processes. [33]

Measures by the EU [95, 96, 97, 98, 100]

The EU has several directives related to public charging infrastructure.

	Alternative Fuel Infrastructure Directive	Trans-European Network – Transport Policy	European Energy Performance of Buildings Directive	Renewable Energy Directive
Description	Aims to ensure a minimum level of infrastructure, full interoperability, full user information, and adequate payment options	Addresses the development of a Europe-wide network of transport covering all regions and linking the most important nodes	Sets technical requirements for residential and nonresidential buildings. This includes requirements that buildings undergoing a renovation which have more than 10 parking spaces need to have at least one charging point and ducting infrastructure to facilitate further installation.	Sets the framework for the deployment of renewables across all sectors for an integrated energy system.
Example of proposals which are currently being revised	Making targets binding and moving from the current target of 1 charger per 10 EVs to fleet- and distance-based targets	Providing sufficient charging capacity for cars at 60 km in each direction	Removing barriers to charging point installation in multi-unit dwellings and requiring charging points to support smart charging	Ensuring charging points in places where EVs are parked repeatedly for long durations, such as parking facilities, have smart charging functionalities. Also, that grid operators make real-time information on the share of renewable electricity supplied available.

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National measures [33, 34]

Governmental authorities on the national level can ensure public charging infrastructure is deployed through multiple ways. They can provide funds to municipalities and regional governments to expand the network, like has been done in France, the UK, and Germany. They can also invest in public-private partnerships, like the Netherlands' Green Deals, or offer incentives to private companies to make the business case more attractive, which is especially suitable with high-need, low-use infrastructure like rapid charging stations.

Local measures [101]

One of the main challenges of public charging infrastructure is in planning and installation. Local governments can choose to streamline these processes. The ICCT has identified two approaches that European municipalities have used:

- Demand-driven approach; uses requests by EV users to determine where infrastructure should be installed in partnership with utilities. This strategy helps ensure minimum utilization of chargers and is suitable for less mature markets, although it does not ensure coverage where EV adoption is low. Amsterdam uses this approach.
- Planning-oriented approach; the city offers publicly- or privately- owned locations for CPO installation. This saves time and money spent on processes like permitting but requires detailed analyses to identify appropriate sites as well as close collaboration. Stockholm uses this approach.

Other areas of intervention include regulations on, say, building codes or interoperability, trial projects around emerging technologies like smart charging, etc.

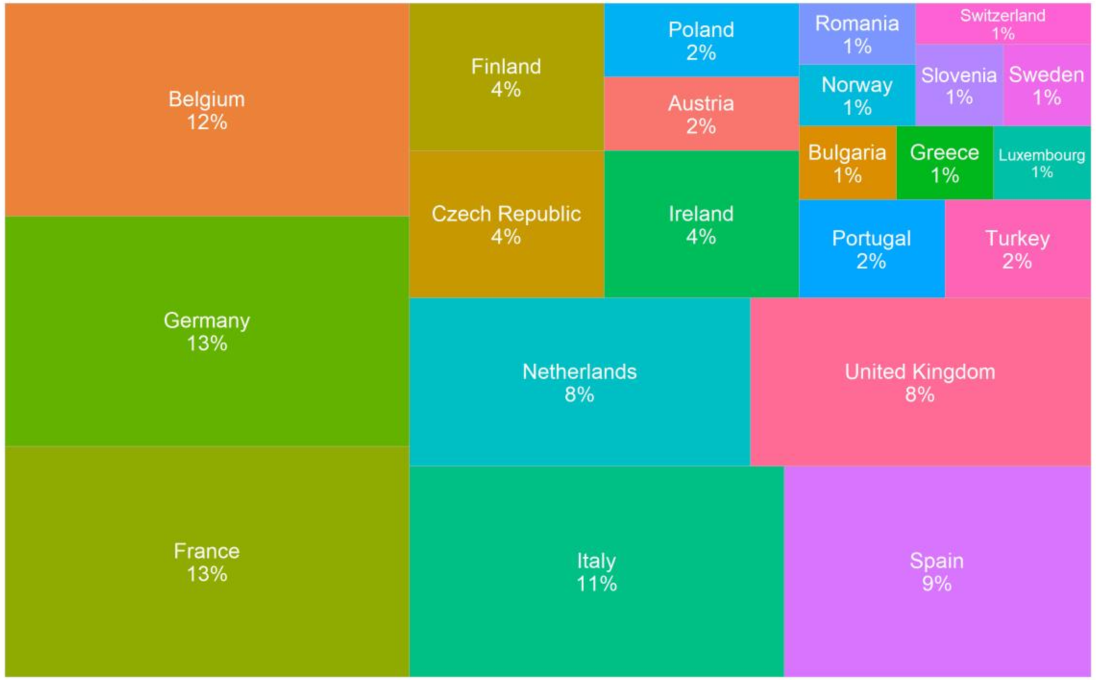
Results of the EPA survey

Introduction

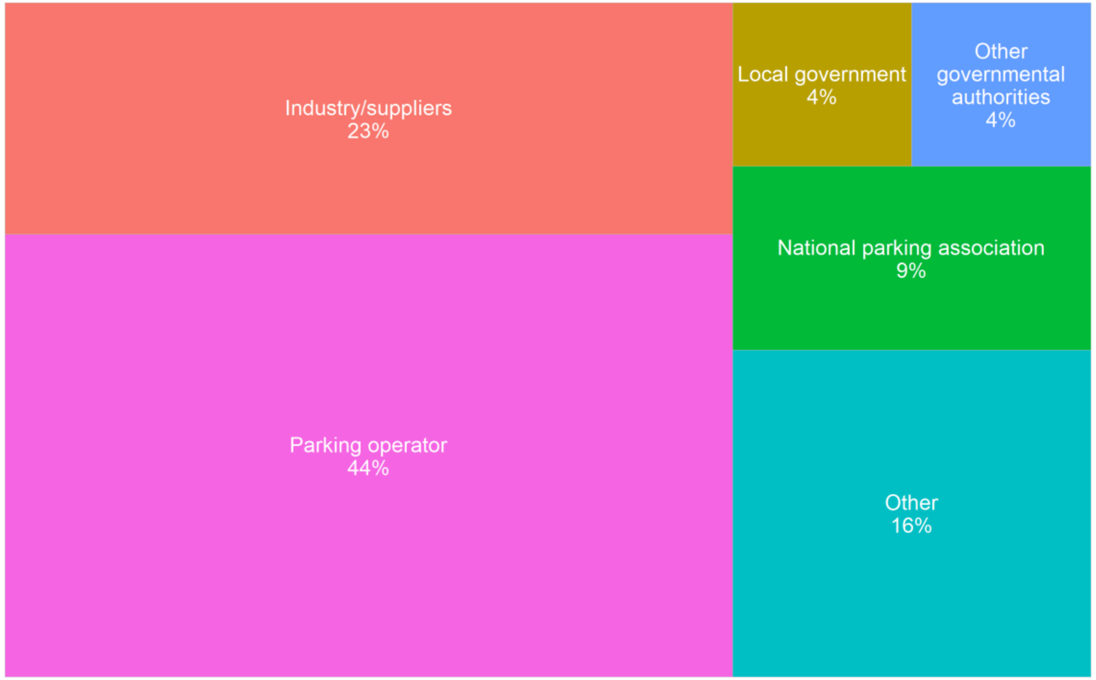
The market for electric vehicle charging is a complex one, operating in the **intersection between energy, mobility and real estate sectors**. Over the past years, the value chain has evolved, with more actors getting involved and carving out strategic roles for themselves. This includes the parking sector; with growth in the electrification of the passenger fleet and the roll-out of charging infrastructure, public and private parking operators are questioning what this means for their business model, and to what extent and how they should adapt, if at all.

To help understand what roles the parking sector can play in the electric vehicle charging infrastructure market, how they are positioned for them, and what challenges and trends are expected to be influential, **the European Parking Association (EPA) distributed a survey among professionals in the parking and mobility sector**. Between May and July 2022, 171 responses were gathered representing sectors such as parking operators and industry/suppliers across 22 countries in Europe.

Countries respondents are based in (N = 171)



Sectors respondents represent (N = 171)

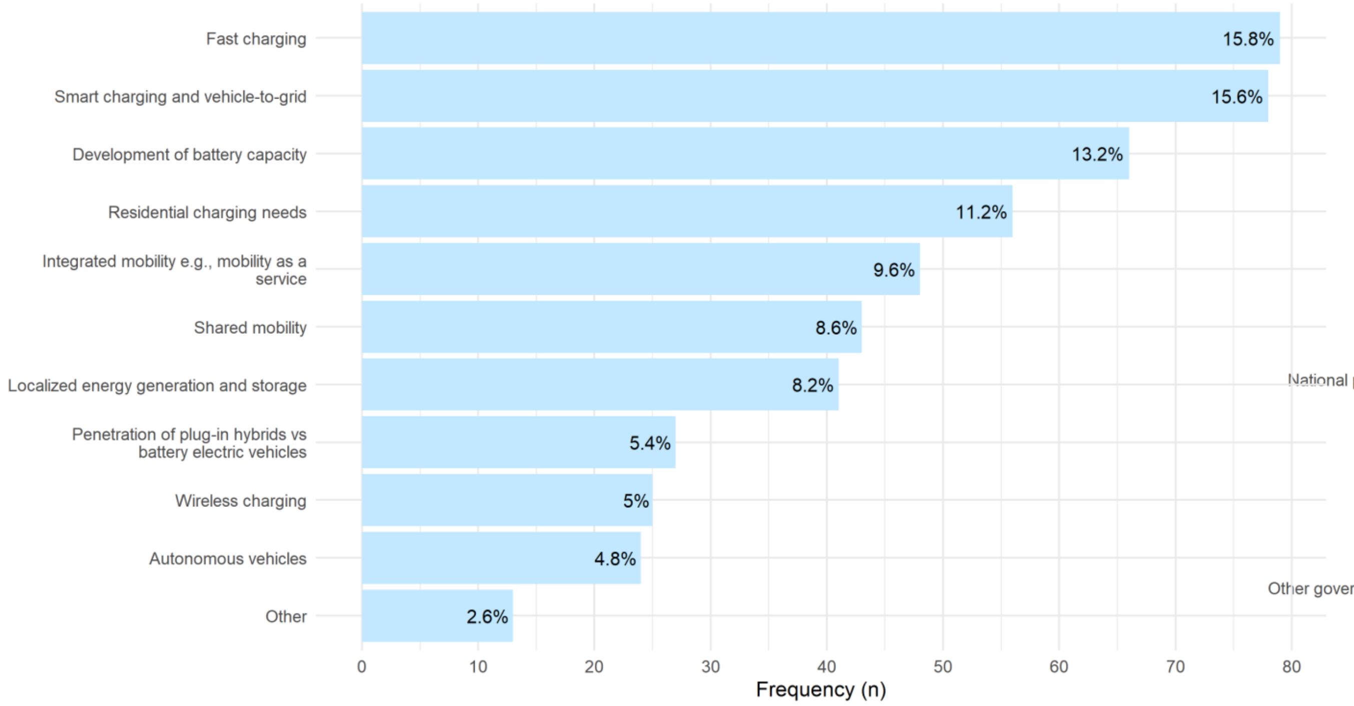


In analyzing and interpreting the EPA survey, it is worthy to keep in mind what countries most respondents are based in, and what sectors they work in. An over- or under-representation of certain demographics can bias results.

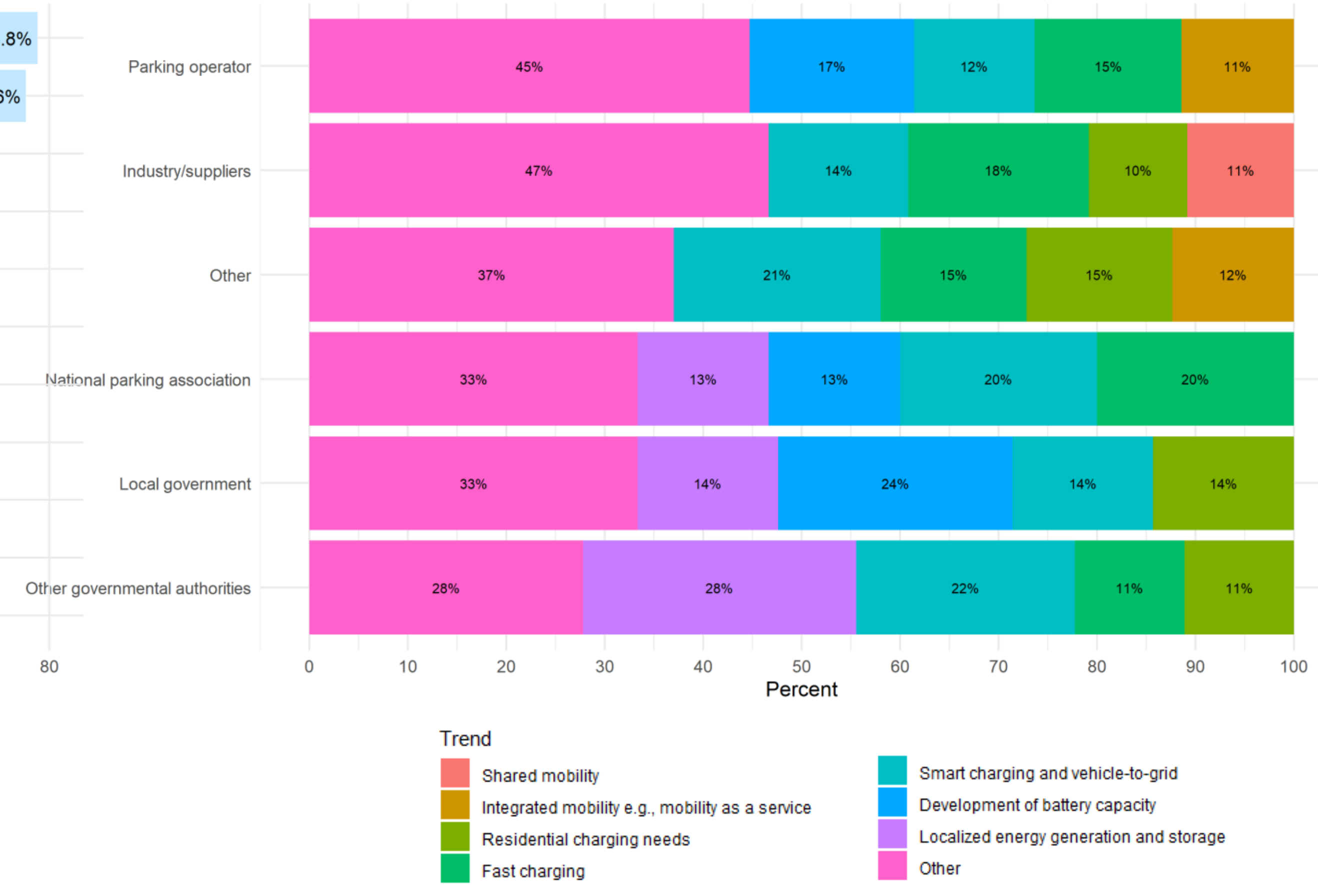
Trends

We first asked participants to identify "the 3 most important trends that will influence the parking sector's involvement in EV charging in the coming 10 years". In total, 11 categories were provided for respondents to choose from, including an "Other" category where the respondent could fill in a trend that had not been mentioned. The frequency distribution of categories can be seen below. It has also been broken down by the respondents' sectors to identify variations in perception.

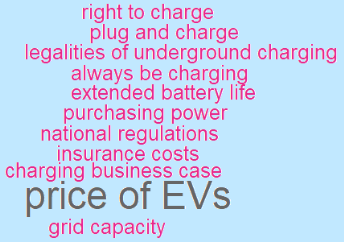
Trends that are said to influence the parking sector's involvement in EV charging



Breakdown of sector by trends said to influence the parking sector's involvement in EV charging

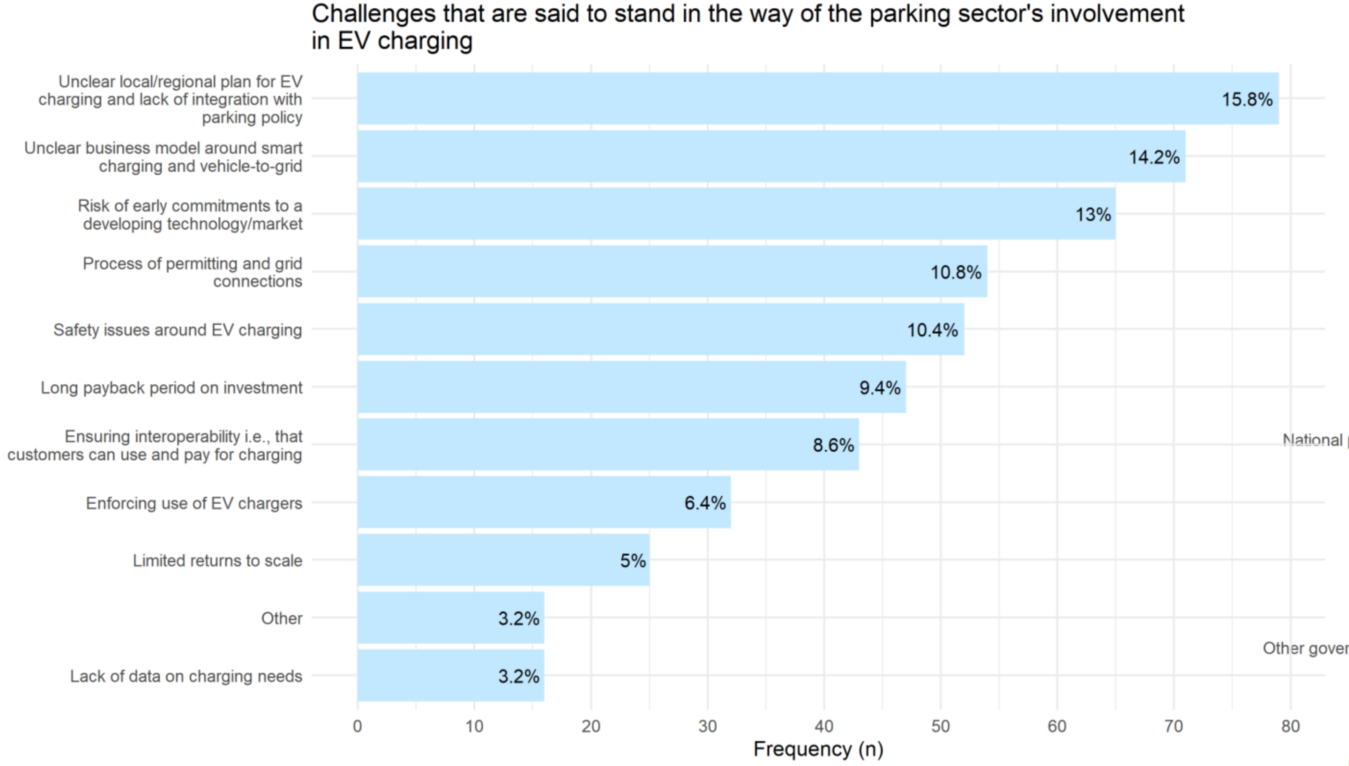


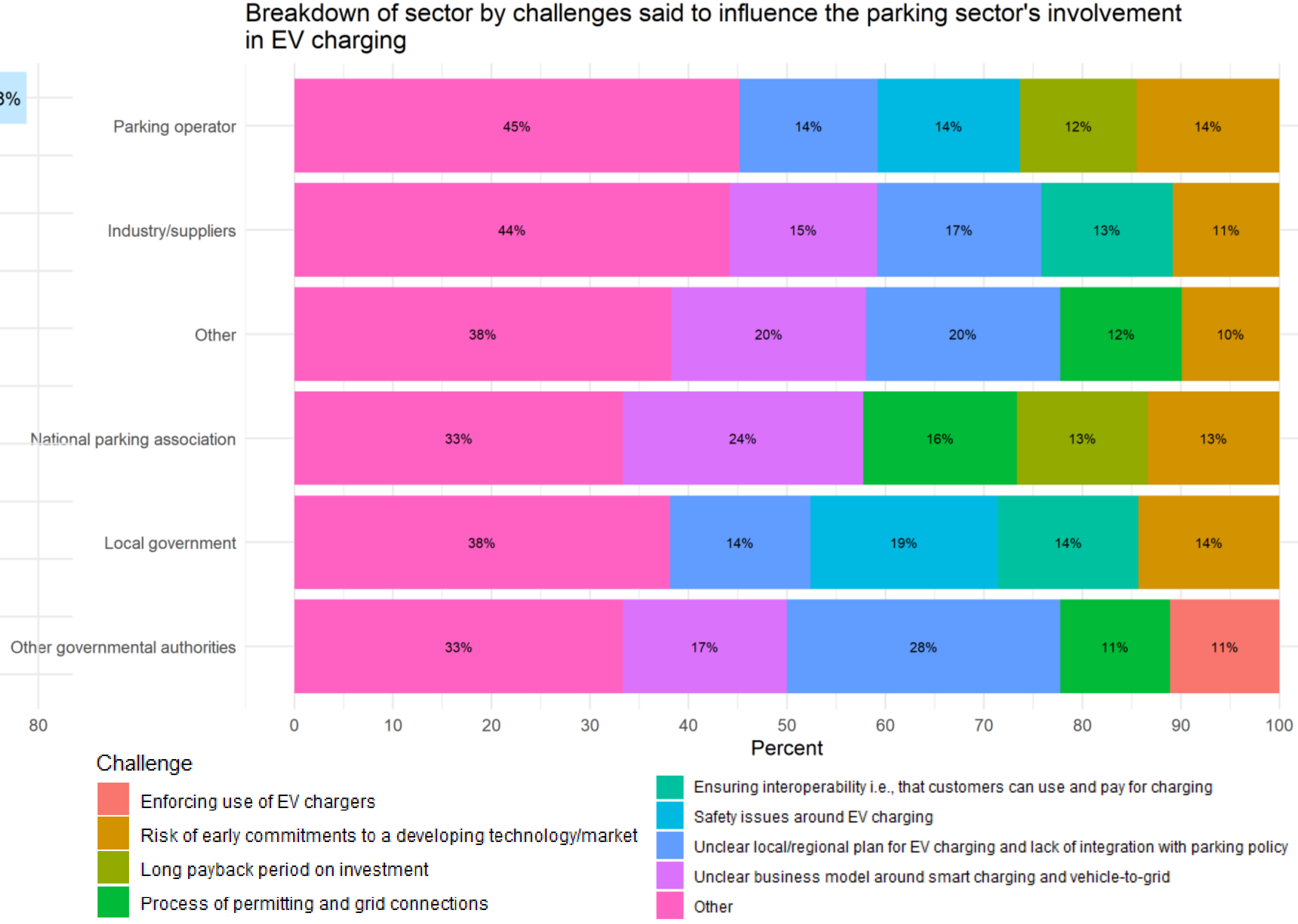
Themes of trends emerging within the "Other" category (n=12)



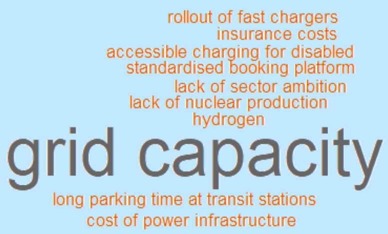
Challenges

We then asked participants to identify "the 3 most important challenges that will stand in the way of the parking sector's involvement in EV charging in the coming 10 years". In total, 11 categories were provided for respondents to choose from, including an "Other" category where the respondent could fill in a challenge that had not been mentioned. The frequency distribution of categories can be seen below. It has also been broken down by the respondents' sectors to identify variations in perception.





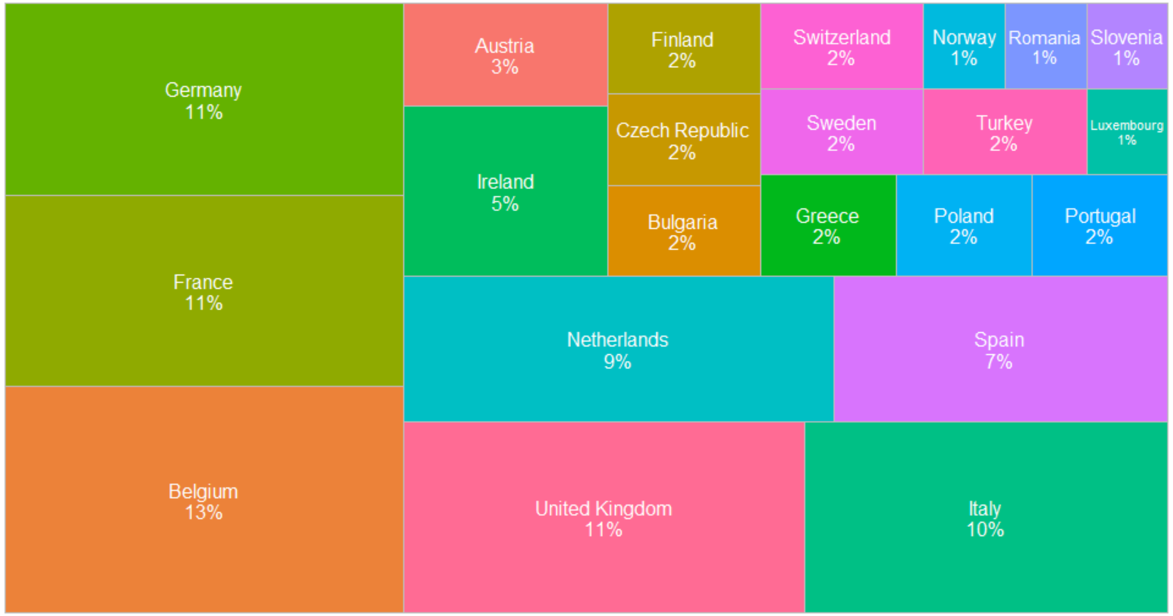
Themes of challenges emerging within the "Other" category (n=16)



Finding the role of parking operators in EV charging

The final question posed to respondents was "What do you think the role of the parking sector should be when it comes to EV charging?". This was an open-ended question where respondents provide answers as brief or as long as they preferred. 70% of respondents answered this question. The representation of countries and sectors are shown below, in addition to an overview of themes that emerged from a text analysis of respondents' answers.

Countries respondents who answered the open question are based in (n = 122)



Sectors respondents who answered the open question represent (n = 122)

Themes that arose from the open questions, which are integrated into analysis in the next section among the other results of the survey, include:

- Activities, services, and resources needed
- Involvement in charging point operation
- Unique value proposition
- Practical challenges and opportunities
- Charging use cases
- Strategic role of the parking sector

Role of the parking sector

The case for involvement

Why might it make sense for parking operators to get involved in EV charging? What inherent advantages might they have over others, and what broader benefits might arise from their involvement?

1

An EV user needs to park their vehicle for it to charge, and, conversely, they might want to charge their vehicle as it parks and multi-task. A parking operator can **satisfy both demands at once**, making for an optimal solution.

2

Placing charging infrastructure in off-street parking garages allows for less crowding of the curb and **more attractive public spaces**.

3

A parking operator is a central entity that manages many parking spots concentrated in one location, and they can usually expect a certain level of activity. This makes for a **greater opportunity to provide flexibility services to the grid**.

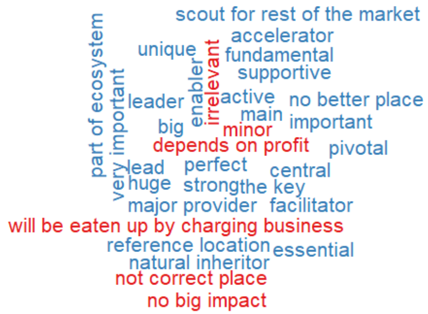
4

Parking operators **already have some of the structures in place** needed for charging, such as payment terminals, reducing necessary investments.

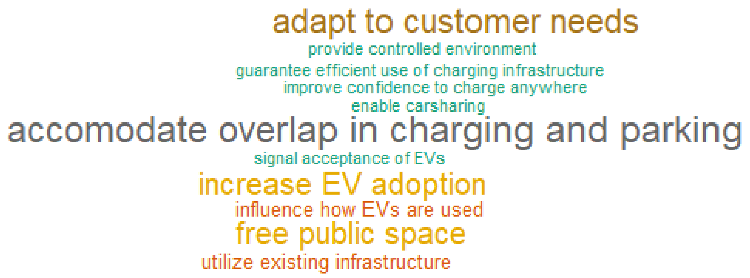
5

At greater EV adoption levels, **we can expect a lack of charging points to be a dissatisfier, especially when people do not have access to home or workplace charging** and must rely on public charging. If a parking operator fails to adapt, they risk having their customers settle for alternatives, whether that be other parking providers or dedicated charging stations.

Sentiments around the parking sector's involvement in EV charging, based on text analysis of respondent's answers surrounding the role of the parking sector (n=38)



The case for the involvement of the parking sector in EV charging, based on text analysis of respondent's answers surrounding the role of the parking sector (n=44)



The case for involvement

Why might it make sense for parking operators to get involved in EV charging? What inherent advantages might they have over others, and what broader benefits might arise from their involvement?

[The role of the parking sector is to] support the move to EV and find ways to balance the needs of the customer: parking and charging, not one or the other.

- Respondent, United Kingdom

We are the only destination charging beside home or work. This gives us a unique role to play as customers don't wait to reload their cars in our car parks. Therefore, we have a special role to play to build a trustworthy environment favorable to the development of BEVs.

- Parking operator, France

The parking sector already has the tools and platforms for parking rules, payment and enforcement. Just add charging!

- Industry/supplier, France

Determining the supply of charging infrastructure

In deciding to what extent and in what form EV charging should be offered, it is important to estimate charging needs and behavior i.e., to find out to what degree charging infrastructure might be utilized, and how. It is also important to consider the conditions under which EV users would be inclined to charge. Here we suggest several questions and parameters for parking operators to consider, and we also outline some of their trends.

1 What does the demand for charging look like locally?

Electric vehicle adoption and use	Electric vehicle type [103]	Electric vehicle range	Access to private charging
More EVs sold and incurring kilometers travelled translates into higher charging needs that need to be met.	The more PHEVs are in circulation, the more frequent charging is needed for lower energy uses, making charging point use more inefficient.	The longer a vehicle can drive without being charged, the lower the need for public charging points.	The lower the access to or preference for private residential or workplace charging, the more EV users rely on public charging infrastructure.

Developments in EV range [8, 9, 102]

The development of battery capacity i.e., range is said to influence the parking sector's involvement in EV charging. Out of 11 trends, it ranked 3rd most frequently chosen in the EPA survey. Among professionals of parking operators and local governmental authorities, it ranked as the most influential trend.

While decreases in battery prices are expected to make larger batteries and longer ranges more affordable, we expect cars with especially high driving ranges to make up a minimal segment of EV stock. The average consumer does not require much range beyond what is already on offer and standard, especially with improvements in charging infrastructure. Furthermore, there are design considerations such as weight that put practical limits on development, hence why we expect only incremental improvements in driving range to occur from here on.

Developments in EV type [3]

Another trend that has been said to affect the parking sector's involvement in EV charging is the penetration of PHEVs vs BEVs. While some countries currently have high levels of PHEV adoption compared to BEV adoption, new sales are expected to decrease due to zero-emission targets and more stringent regulations around PHEV production. Accordingly, we expect BEVs, and their charging behavior, to be the norm in the future.

The professionals we have surveyed appear to concur with this finding. They place little importance on the type of EV as a factor that influences the parking sector's involvement, with it ranking 8th out of 11 options and seeing only 5% of votes.

Determining the supply of charging infrastructure

In deciding to what extent and in what form EV charging should be offered, it is important to estimate charging needs and behavior i.e., to find out to what degree charging infrastructure might be utilized, and how. It is also important to consider the conditions under which EV users would be inclined to charge. Here we suggest several questions and parameters for parking operators to consider, and we also outline some of their trends.

Developments in access to private charging [16, 50]

One of the trends that is said to influence the parking sector's involvement in EV charging is the development of residential charging needs. In our survey, it ranked 4th out of 11 trends. If EV users do not have access to workplace or home charging, as is the case in dense cities, they will tend to rely on public charging. This need will increase as cities densify further. However, w**here EV users will go to charge their batteries remains a topic of debate, one that is said to be influenced by the outlook on fast charging**.

2 What does the demand for charging look like for the parking operator?

Size	Location	Parking duration	Charging profiles
The larger the parking facility, the higher the occurrence of EV users.	Different locations will vary in their levels of activity, the customers they serve, and their needs. For example, strategic locations in the city center or by high-traffic transport corridors can expect a lot activity, and by a variety of users.	The longer the typical parking duration, the more acceptable slower charging points are likely to be.	There are multiple types of EV users, each with their own needs and patterns of charging (which can be complementary, ensuring more consistent use throughout the day). For example, residents tend to charge overnight for long hours, while shared vehicle users or high-mileage applications such as taxis tend to charge in shorter bursts spread out throughout the day.[103, 104]

Parking operators should contribute to make a proposition of the appropriate locations, type and volume of EV chargers to be implemented based on the typology of users instead of applying the same quotas for all parking infrastructures.

- Parking operator, France

Determining the supply of charging infrastructure

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The development of faster charging solutions –opportunity or threat? [8, 9, 16, 50, 55, 101, 104, 105, 106, 107]

When survey respondents were asked to choose the most important trends affecting the parking sector, **fast charging ranked 1st**.

Developments in fast charging can be seen as an opportunity. If speeds of charging improve and costs of hardware and installation in urban areas reduce over time, offering fast charging opportunities can be a way in which a parking operator fulfils customer needs. **Several types of EV users have charging patterns conducive to fast charging**, such as high-mileage, commercial users like taxis and shared vehicles, or freight vehicles. Furthermore, fast charging might be desirable to a larger target group as a as a way to kill time between appointments, or as a back-up option during longer trips or when slower public charging infrastructure is lacking or is inaccessible. For example, fast charging plazas in residential areas could provide a reliable and flexible option to deal with a lack of access to private charging while also providing a more feasible business case.

However, many suppose that developments in charging speeds will create an overwhelming preference for charging at enroute stations, such as petrol stations, leading to the collapse of charging while parking, say at destinations or transit stations. While charging at enroute stations is expected to provide a close replica to the ICE refueling experience, we do not expect that it be a pure substitute to slower alternatives. **We believe that the act of charging will, still, very much be integrated into a person's daily travel destinations, and into the community.** We have several reasons to suggest this:

- The use of faster charging speeds are contingent on the vehicle being able to support this use. Most EVs sold currently support up to 150 kW charging speeds, after which batteries begin to degrade. PHEVs are especially limited.
- **EV users have been reported to charge their vehicles like they do their smartphones, topping up as they go, when the opportunity arises, despite substantial battery life.** While this behavior may be partially driven by the current state of charging infrastructure (both in speed and in availability), a lock-in effect is not unlikely. More importantly however is that ***"it will always be convenient to charge somewhere that you are parked anyway"***, as Connected Places Catapult succinctly puts it. Charging and parking demand overlap, and we can expect people to continue to make use of their complementarity to save time and effort.

Determining the supply of charging infrastructure

In deciding to what extent and in what form EV charging should be offered, it is important to estimate charging needs and behavior i.e., to find out to what degree charging infrastructure might be utilized, and how. It is also important to consider the conditions under which EV users would be inclined to charge. Here we suggest several questions and parameters for parking operators to consider, and we also outline some of their trends.

3 What might a parking operator need to consider to ensure demand is met?

Pricing [8, 16, 61]	Access and awareness [8]	Space layout and accessibility [8, 108]	Allocation of space [8, 108]	Charging hogging [8, 86, 87, 108]
The higher the rate for charging, the more prohibitive it can be, especially as an alternative to private charging. The competitive position can worsen when a parking premium is factored in.	Access and payment methods can determine whether an EV user opts to charge, which is why coordination with E-MSPs is necessary. Additionally, the availability of charge points needs to be publicized and integrated into databases and navigation systems.	Charging bays should be visible, clearly marked, and designed to be accessed by people with different needs e.g., the disabled. Implications on curbside space for pedestrians also need to be dealt with.	Vehicles that do not need to charge, whether they are ICE vehicles or EVs, might take up charging bays. To avoid this, parking operators need to strategize on the allocation of space.	It is often the case that vehicles stay connected to charging points for longer than the charging duration. Like with space allocation, this means that even though a parking operator may have enough charging points to theoretically satisfy demand, customer behavior can create inefficiencies that reduce their offer.

"

[The parking sector's] role should be under a "carrot and stick" approach, by providing parking spaces for EV (including concerns for vulnerable users like people with disabilities and the elderly), but also by providing enforcement to ensure that there is no abusive use of these parking places.

- Respondent, Belgium

"

The parking industry needs to recognize that 'space' will, in most instances, be synonymous with charging and therefore park and charge will need to be able to be dynamically and effectively priced with booking capability to ensure space-charge availability with suitable enforcement to create the required and desired certainty and compliance.

- Industry/suppliers, United Kingdom

Determining the supply of charging infrastructure

In deciding to what extent and in what form EV charging should be offered, it is important to estimate charging needs and behavior i.e., to find out to what degree charging infrastructure might be utilized, and how. It is also important to consider the conditions under which EV users would be inclined to charge. Here we suggest several questions and parameters for parking operators to consider, and we also outline some of their trends.

Space allocation strategies [8]

- Designating bays for use only by plugged in EVs; this is common practice but is effective only at low proportions of charging bays and EV use. As EVs become the norm and more charging points are required, restrictions will not serve a purpose anymore, and, if charging demand happens to be low, capacity will be significantly reduced.
- Allocating vehicles to parking spaces according to their need to charge; this can be done prior by requiring reservation, or as vehicles come in with the aid of signage or wayfinding technologies.
- Changing the behavior of non-charging vehicle users; this can be done through nudge tactics and signage. However, relying on compliance is likely to not be very effective, so the number of charging points needed might need to increase to accommodate undesirable behavior.

Combating charging hogging [87, 93, 94]

Pricing can prevent hogging, as is most commonly seen with rapid chargers like Tesla's. However, charging extra for connection times that exceed charging duration might conflict with the business model of the parking provider whose main value proposition is for the customer to be able to park for as long as they need.

Accordingly, it might be more worthwhile for parking operators to explore the use of incentives like financial rewards, nudges like connecting EV users to one another, and valet charging. Valet charging is especially applicable in the controlled environment of a parking lot and has been shown in early experiments to help avoid grid connection costs. However, valet parking as a whole is not a particularly common practice in Europe.

Use cases

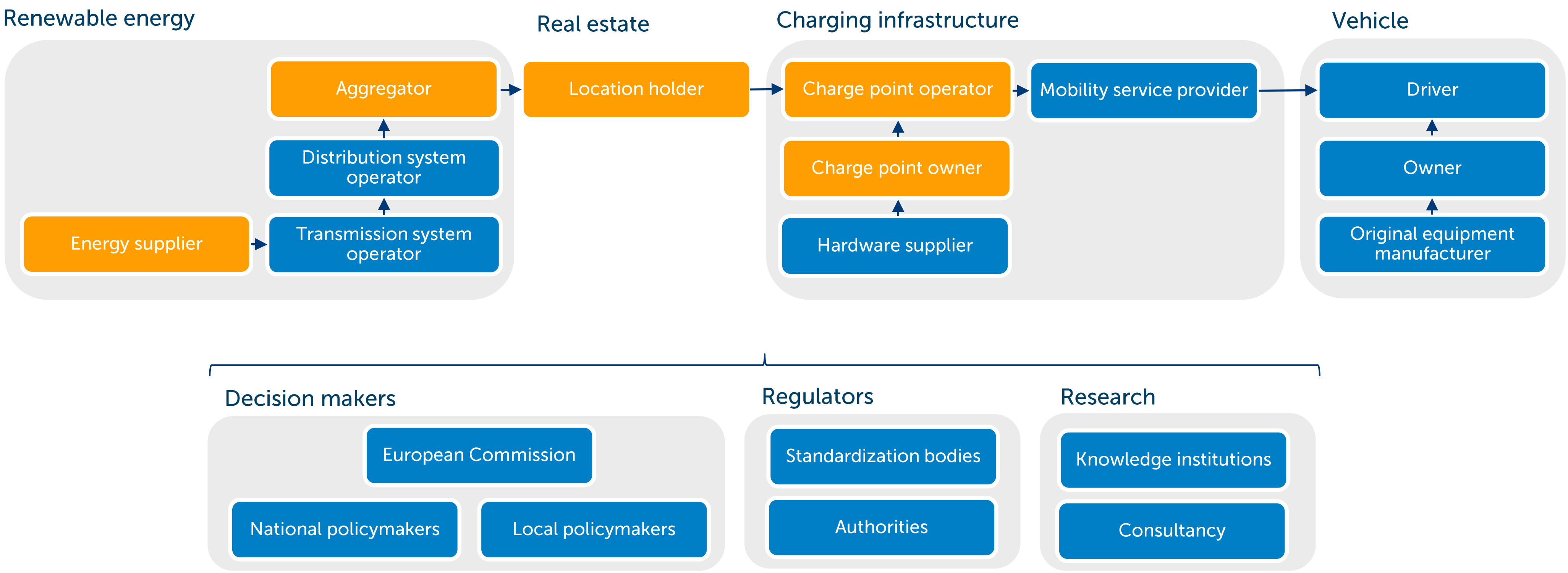
Parking operators provide parking spaces along streets, in lots, or in garages, in different areas of the city and for different types of customers. These differences, among others, make it so that business models can be designed in various configurations. Here, we outline some basic offerings that we think parking operators are uniquely positioned to provide.[15, 16, 33, 45, 46, 47, 48, 49]

	Off-street residential charging	Off-street destination charging	Off-street transport hub e.g., park and ride or public transport terminals
Users	Residents	Variety including visitors, business employees, and visitors servicing business operations	Variety including commuters, visitors, shared vehicles, taxis, and public transport vehicles
Behavior	Mainly overnight, predictable	Varied dwell times, generally high levels of activity spread throughout the day	Varied dwell times spread throughout the day, although afternoon charging is likely with commuters
Speed	Slow	Mix	Mix
Value propositions	Cost-effective, reliable and convenient charging matching typical parking behavior Gives a home to "homeless fleets" of EVs that do not have access to private chargers	Opportunity to combine charging with other activity and top up Drives commercial activity	Alternative to workplace charging Opportunity to combine charging with other activity and top up Promotes multi-modal mobility and use of last mile options
Opportunities to explore	Smart charging subscriptions with different levels of compensation in exchange for certain durations and scheduling of charging as well as flexibility to use vehicle Multi-functional neighborhood hub Mobility hub	Ad hoc smart charging compensation Potential to provide limited ultra-fast charging options if location is on a high-traffic transport corridor Logistics hub	Ad hoc smart charging compensation, although smart charging subscriptions can be explored with commuters Local energy generation and storage may be suitable if space allows, although public transport hubs tend to be equipped with high grid capacity which they make use of intermittently Mobility hub

Other transport hubs on the outskirts of the city e.g., airports and ports may be especially suitable for smart charging due to their long dwell times (>24 hours).

EV charging value chain

No matter the charging use case, parking operators will need to decide their role in the value chain. Aside from being a location holder, there are multiple other roles and combinations of roles within the value chain that a parking operator can choose and orient their business model around.



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The more traditional role of the parking operator

In practice we see that parking operators' involvement in the EV value chain does not usually go beyond their role as a site host, entering into lease and agreements with third parties who then install and operate charging points at their site. While such an arrangement ensures that parking operators can fulfil charging needs and improve their competitive advantage, expanding their involvement opens up additional opportunities, from potential control over smart charging processes to direct interaction with customers.

Towards owning and operating charging points

There are several avenues that parking operators could explore when it comes to investing and operating charging infrastructure, bearing in mind that the energy market is highly regulated and may pose limitations.

Broadly speaking, parking operators could choose to own their own charging points. Here, they have the choice of operating them or their day-to-day operations and maintenance responsibilities to a third party. They also could enter into more complex contractual agreements where expertise, risks, and benefits are shared, and additional specifications are agreed on – for example, that the CPO use smart charging functionalities to help optimize the parking lot's energy use in combination with local energy generation and storage.

> *[Parking] operators have to decide: outsourcing of EV charging or integration into an own business model.*
>
> *- Respondent, Germany*

More about the business case of being a charging point owner and operator

Business case of operating and owning charging points

Capital expenses: Procurement costs [33, 15, 58, 37, 56]

Charger hardware

The higher the power rating of the charger, the higher the cost. Other cost drivers are configurations like smart vs dumb charging, the type of authentication and payment system, wall-mounting versus freestanding, and the need for weatherproofing, among others.

Contracts

Network and data contracts are usually arranged; they help with interoperability and in adhering to open standards. Maintenance contracts are also usually procured, and they vary based on the site.

Software

The software that is needed to operate chargers usually comes together with the purchase of hardware in one package to ensure the buyer's needs are met and to ensure each component is compatible with the other. Software should be ideally compliant with open standards.

Other make-ready infrastructure

This broadly includes all necessary electrical infrastructure between the grid interconnection and the chargers, like step-down transformers. Typically, they are at about 30-40% of capital costs of installation. If spaces are pre-cabled, costs are reduced.

Grid capacity

The capacity for the grid to host new chargers depends on the location of the site, the number of charging points, the technical features of the chargers, the capability for managed charging, and the capacity of distribution transformers or distribution grid feeders. These factors are evaluated by the DSO to understand the need for grid reinforcement or other flexible solutions, and their costs.

If grid upgrades are needed, costs are either borne entirely by the charging point operator or can be divided as part of an existing investment policy – if network planning is done in advance and interventions on the same sections of the network are coordinated.

In the EPA survey, we gave the opportunity for people to write what challenges they believe stand in the way of the parking sector's involvement in EV charging. **A lack of grid capacity was most suggested.**

Business case of operating and owning charging points

Capital expenses: Soft costs [37, 48, 101]

Overview

These are unpredictable upfront costs associated with permitting processes, meeting building codes, finding a suitable site, obtaining grid connections, and so on.

In the US, soft costs have pushed charger installation costs three to five times past the cost of the charger. Although the cost differential is said to be lower in Europe, soft costs are still significant – for example, in Oslo, permits, regulation, and public tender processes are said to have driven an approximately 80% increase in the average price of a public AC regular charger over three years.

A closer look at the process of grid connections

One of the most reported drivers of soft costs is the process of establishing grid connections. Installing and connecting an EV charging point in and of itself takes a matter of days but connecting the charging point to the grid can take up to 2-3 years from contract agreement to completion, according to the CPO Greenway's experience with DSOs in Poland. This is not just an issue in Eastern Europe either. In Amsterdam, the duration of approving and installing a public AC regular charger can take more than 9 months, and in London, can go up to (and maybe exceed) 14 months.

These issues might occur for several reasons:

- Non-transparent timelines and milestones and uncommunicated delays
- Lengthy processes of negotiations with landowners and acquiring permits and approvals from local authorities and regulatory entities
- Unclear decision-making criteria making it so that requests are declined without justification

In the EPA survey, we asked what challenges are said to stand in the way of the parking sector's involvement in EV charging. Processes of permitting and grid connections ranked 4th out of 11 challenges. Among representatives of national parking associations, it ranked 2nd.

Business case of operating and owning charging points

Capital expenses: Local requirements [37, 109, 110, 111]

Overview

Complying with regulatory requirements can add to the costs and complexity of installation. Potential areas of regulation include location, user authentication, types of plug connections, safety, and data sharing protocols.

A closer look at safety requirements

While EVs do not pose a higher safety risk than ICE vehicles, incidents involving EVs require a different management approach, particularly in parking garages. Batteries produce fires that last for a long duration, and they can also reignite, so a large amount of water is needed. The battery pack is also more difficult to find on a car. For these reasons, locations need to be equipped with necessary precautions which can be costly and lengthy.

Guidelines will differ according to region. In France, for example, non-binding guidelines stipulate that, unless the parking garage is equipped with water sprinkler systems or is highly ventilated, chargers should be installed on the ground floor or levels immediately above or below it, charging power should be limited to 150 kW, and there should be at maximum 20 chargers per site. Parking garage operators may also find difficulties arranging insurance as a result and may be charged more.

In the EPA survey, we asked what challenges are said to stand in the way of the parking sector's involvement in EV charging. **Safety issues ranked 5th out of 11 challenge. Zooming into responses from parking operators, we see that it ranks 1st.** Furthermore, respondents from Belgium and France were highly represented.

Business case of operating and owning charging points

Operating expenses [9, 33, 61, 112, 113, 114, 124, 127]

Electricity costs

The purchase of electricity is the most critical operating cost driver. Retail electricity prices consist of the energy component, network component, and taxes and levies. Often, tariff structures include demand charges, which are based on the highest amount of power drawn by the charging point in a given period - usually monthly. These can make up more than 50% of monthly electricity bills and are especially high when it comes to ultra-fast chargers.

Electricity costs can be reduced through smart charging, in its most basic sense of utilizing time-of-use tariffs to the use of emerging technologies such as vehicle-to-grid. Estimates on the monetary savings of smart charging differ from geographic region and according to the service provided. According to a 2021 US study, the monetary value of smart charging and vehicle-to-grid amounts to $87 and $2,850 per vehicle-year respectively, specifically in the case of facilitating renewable energy integration and reducing required stationary storage. In an interview we conducted with someone from a European OEM, savings from smart charging, depending on the service, were estimated to be between €100-1,000 per vehicle-year.

Site rent

Site rent applies when the land is not purchased and a rental fee is incurred.

Back-office

Back-office costs are the expenses related to the management of the charger and the user. They include items as customer support services, user registration, issuing RFID cards for payment, and software provision, upgrade, and development costs.

Maintenance

Maintenance costs include routine checks and associated services like upgrading spare parts. They can also be unplanned, and in that case cover one-off events like vandalism and non-warranty part failures.

Business case of operating and owning charging points

Revenues [33, 34, 114, 115, 116]

Electricity revenue

The purpose of the EV charging point is to provide electricity, so the most straightforward and direct way to make revenue is to sell electricity at a markup. There are various pricing structures in the market – paying per kWh, per duration, per session, or through an annual or monthly subscription. In Europe, volumetric fees are common, as well as subscription fees, which helps charging point operators, especially in an underdeveloped market with low utilization rates, keep steady revenues.

It is important to note that the EV driver's willingness to pay depends on their state of charge i.e., their battery status as related to their battery capacity, as well as their electricity price reference point, which is lower for consumers with access to private charging.

Advertising

Like gasoline stations, charging stations can integrate advertising into their business model, especially in locations that are highly visible and frequented.

Partnerships

Other partnerships can also help drive up utilization. This depends on the use case and strategy, but retailers, for example, are a common partner; EV users have been shown to have a higher dwell time than other customers, and the location of a charger can stimulate shopping that otherwise wouldn't have been done.

Adjacent services

CPOs can choose to provide services adjacent to charging, such as battery swapping, charger reservations, etc.

Back to the EV charging value chain

EV charging value chain

No matter the charging use case, parking operators will need to decide their role in the value chain. Aside from being a location holder, there are multiple other roles and combinations of roles within the value chain that a parking operator can choose and orient their business model around.

Producing and storing local energy [49, 117, 120]

One of the benefits of renewable energy is that it can be generated on-site, reducing reliance on the grid and costs of grid reinforcement. Parking operators may choose to install solar panels, supported potentially by stationary batteries which store additional energy for when it is required or optimal to be used. As electricity trading between neighbors and communities develops from its current stage of early maturity, the potential for selling remaining energy to parties other than electricity suppliers also grows.

Practicalities of powering charging with solar energy in parking lots [117, 118, 119, 120]

- One parking space can provide 75-100% of the energy needed to charge an EV, depending on solar power yield and charging requirements. Smart charging can smooth variations out by optimizing charging according to the amount of solar power available, the needs of the vehicle, and potentially market prices.
- Solar parking lots have been shown to have high upfront investments costs. According to a study out of the US, a solar powered charging point at a public parking lot is estimated to have a 17-26.5 year payback period.
- Appropriate site selection is crucial. Installing solar panels at surface carparks is cheaper than multi-level carparks. In addition, as electricity trading between neighbors and communities develops from its current early maturity, locations next to high energy users such as airports or large commercial premises might end up performing well if remaining energy can be reliably sold to them rather than electricity suppliers.

In the EPA survey, we asked what trends are said to influence the parking sector's involvement in EV charging. While localized energy generation and storage did not score particularly high (7th place out of 11 options), it is noteworthy to mention that, among governmental authorities (not local), it was ranked first.

The parking operator's roles in the EV charging value chain

No matter the charging use case, parking operators will need to decide their role in the value chain. Aside from being a location holder, there are multiple other roles and combinations of roles within the value chain that a parking operator can choose and orient their business model around.

Aggregating EVs at the level of the grid [121, 122, 123]

While still at its infancy, parking operators may also choose to manage the charging of EVs and provide flexibility services to the grid. **It has been suggested by several studies that parking garages are among the best candidates for the intermediary role between EVs and the energy market**; they have access to many vehicles on a regular basis, have existing IT infrastructure for billing and contractual frameworks with customers which can be tailored to pass on revenues.

Business case challenges of vehicle-grid integration [27, 63, 121, 122, 123]

An unclear business model around smart charging and vehicle-to-grid is the 2nd most reported challenge that the professionals we surveyed believe impacts the parking sector's involvement in EV charging. We highlight some challenges that appear in the case of frequency regulation, found in other studies:

- Aggregators may not be able to participate in the regulation market because they cannot guarantee the necessary energy with full reliability.
- To be able to balance incidents of high grid frequency, aggregators would need to keep a certain amount of power available by not allowing some vehicles to charge upon entering the garage, forfeiting revenues from selling energy. These opportunity costs have been shown to outweigh revenues from responding to regulation incidents since they do not necessarily occur frequently throughout the year.

One additional point to note here is that **the use of second-life EV batteries for flexibility is increasing among OEMs, and is likely to compete with EV aggregation,** aside from other more reliable flexibility sources that do not necessarily rely on compliance from the user.

Needs of vehicle-grid integration [16, 27, 56, 63, 123, 125, 126]

To be suitable to manage charging processes of EVs at public charging points, several conditions need to be ensured:

- EVs with sufficient battery capacity and, in the case of V2G or V2B, capacity for bidirectional energy flows (which is expected to grow as a functionality from 2022 onwards)
- Critical mass of connected EVs i.e., a captive fleet; according to the International Renewable Energy Agency, around 500 connected EVs are required to make power provision viable at the wholesale level
- Charging points that are smart and of sufficient capacity, complemented with an energy measurement system e.g., smart meters
- Sufficient connection duration of ideally more than four hours, the longer the better
- Reliable connection duration with low risks of unplanned disconnection

Accordingly, the following information is needed from the side of the EV user in addition to a contractual agreement to hand over control:

- Type of vehicle
- Current plugged-in status and state of charge
- Expected state of charge and time of departure

For these needs to fulfilled, **parking operators will need to ensure they have some say in the management of the charging point or that they directly operate it.**

The parking operator's roles in the EV charging value chain

No matter the charging use case, parking operators will need to decide their role in the value chain. Aside from being a location holder, there are multiple other roles and combinations of roles within the value chain that a parking operator can choose and orient their business model around.

Aggregating EVs at the level of the building [127, 128]

By shifting loads from peak pricing times to periods where electricity costs are lower and smoothing demand to avoid charges, reductions in electricity costs of buildings can be achieved. Parking operators can venture into this, as well as providing back up systems for buildings in case of outages. Contractual agreements may be easier to arrange with real estate owners than grid operators given the lower amount of power and vehicle availability needed.

Vehicle-building integration at Vulkan Parking Garage, Oslo [129, 130]

A pilot project from 2017-2020 at Vulkan Parking Garage in Oslo, Sweden shows one example of a business model in which EVs are aggregated and charge smartly, providing benefits at the scale of a building. The garage has over 100 charging outlets configured for peak shaving. It serves vehicles used by residents as well as non-residents e.g., shared cars and freight vehicles. Stakeholders in the business model include:

1. Parking garage operator; rents the parking space from the real estate owner and receives profits from parking
2. CPOs; owns and operates smart chargers, saves on electricity, and receives profits from charging services
3. Real estate owner; rents the parking garage, invests in a battery energy storage system, and invests in an energy management system. The benefits they receive are rent of the parking garage, a portion of parking profits, a portion of charging profits, and savings in their electricity bill.
4. City council; rents parking spaces for overnight use by residents and pays for the electricity used for charging
5. EV owners/users; enter an agreement for third party control of their vehicle's charging process and gets a reduced charging cost in return

Key takeaways

Key takeaways

With the dramatic growth of EV adoption rates and European-wide commitments to decarbonization, the EV transition is said to be almost inevitable. The fact, however, is that its success is highly contingent on the development of a robust, convenient, and reliable network of charging infrastructure. Looking at the current state of the market and its outlook, we have identified several trends worthy of consideration by parking operators.

1

There are geographic differences in charging infrastructure rollout

The development of charging infrastructure has been shown to be more robust in Western European countries compared to others, with 79% of public charging points concentrated in just five countries. While growth in charging infrastructure coverage will undoubtedly be needed across the board to support full electrification, countries of Eastern Europe will need to catch up quickly to prevent further polarization.

2

Demand for public charging infrastructure will grow and will not be limited to rapid charging solutions

As electrification of the vehicle fleet grows and extends to the masses, demand for reliable and, importantly, affordable public charging infrastructure will grow. The quantities and types of charging solutions needed will depend on various factors, from the local vehicle mix to the types of EV users, but perhaps the most critical determinant of public charging needs is the extent to which people have access to private charging opportunities. In high-density urban areas where multi-unit dwellings are prevalent, it is likely that EV users will need to rely on public charging infrastructure. This raises the crucial question of where EV users will go to fulfil their charging needs.

Enroute rapid charging stations are commonly perceived to be a threat to charging while parking, say at destinations or transit stations. While charging at enroute rapid charging stations is expected to provide a close replica to the ICE refueling experience, and while there are indeed several types of EV users that have charging patterns conducive to enroute rapid charging, such as high-mileage commercial taxis and shared vehicles, we do not expect a substitution effect. We expect that the act of charging will, still, very much be integrated into a person's daily travel destinations and into the community. EV users have been reported to charge their vehicles like they do their smartphones, topping up as they go, when the opportunity arises, despite substantial battery life. Although this behavior may be partially driven by the current state of charging infrastructure, a lock-in effect is not unlikely. More importantly however is that charging somewhere that you are parked anyway will always be convenient. Charging and parking demand overlap, and parking operators can expect people to continue to make use of their complementarity to save time and effort.

Key takeaways

With the dramatic growth of EV adoption rates and European-wide commitments to decarbonization, the EV transition is said to be almost inevitable. The fact, however, is that its success is highly contingent on the development of a robust, convenient, and reliable network of charging infrastructure. Looking at the current state of the market and its outlook, we have identified several trends worthy of consideration by parking operators.

3

The case for the involvement of the parking sector in EV charging, in one way or another, is strong

The involvement of parking operators is still at its infancy and there remains a great deal of uncertainty surrounding the business case, especially with bottlenecks like lengthy and unclear processes of permitting and establishing grid connections, as well as a lack of integration of the parking sector in long-term policy and planning. However, EV charging can be regarded as a natural fit for the parking sector for several reasons.

- An EV user needs to park their vehicle for it to charge, and, conversely, they might want to charge their vehicle as it parks and multi-task. A parking operator can satisfy both demands at once, making for an optimal solution.
- Placing charging infrastructure in off-street parking garages allows for less crowding of the curb and more attractive public spaces.
- A parking operator is a central entity that manages many parking spots concentrated in one location, and they can usually expect a certain level of activity. This makes for a greater opportunity to provide flexibility services to the grid.
- Parking operators already have some of the structures in place needed for charging, such as payment terminals, reducing necessary investments.
- At greater EV adoption levels, we can expect a lack of charging points to be a dissatisfier, especially when people do not have access to home or workplace charging. Some degree of business model innovation will be necessary to stay relevant amidst a rapidly evolving landscape. Parking operators will need to be proactive about this.

4

Smart charging is an opportunity worthy to explore

EVs have the flexibility to manage their electricity demand which allows them to act as assets to the energy system so long as they are parked and plugged in. With smart charging, the fact that vehicles are parked for about 95% of their lifetime becomes an opportunity to create value and reap monetary benefits, especially in cases with longer connection times and more predictable vehicle use. Parking lot operators have been suggested to be suitable candidates to fill an intermediary role between EVs and the energy market; they have access to many vehicles on a regular basis, have existing IT infrastructure for billing, and contractual frameworks with customers which can be tailored to pass on revenues.

While the practical application is still at its infancy, very much depends on the use case, and is not without its technical, economic and social challenges, there is no doubt that smart charging will play a large role in the transition and that parking operators can shape a strategic role for themselves. This starts with experimenting and building knowhow.

Appendix

Abbreviations

EV	Electric vehicle
BEV	Battery electric vehicle
PHEV	Plug-in hybrid electric vehicle
CPO	Charge point operator
E-MSP	E-mobility service provider
OEM	Original equipment manufacturer
DC	Direct current
AC	Alternating current
CSS	Combined Charging System
CHAdeMO	Charge de Move
V2G	Vehicle to grid
V2B	Vehicle to building
DSO	Distribution system operator
TSO	Transmission system operator

More about the desk research and interviews

Desk research of existing literature and data

- A literature review was conducted encompassing academic and non-academic research papers and reports to inform the research.
- Quantitative data was used to create figures and maps. Where available, the scope was limited to 32 countries – those of the European Union and the European Free Trade Association, in addition to the United Kingdom.
- Quantitative data sources include:
  - Eurostat for the stock of EVs, population, kilometers of road, share of population by housing type, and geographic boundaries – extracted via R package "eurostat" or downloaded directly from the website
  - ACEA for the stock and new registrations of EVs – manually copied from annual and quarterly reports
  - Open Charge Map (OCM) for information on operational, non-private charging points - extracted through the community's GitHub page on which live point-of-interest data is exported per country. The date of extraction was the 12th of January 2022.
- The use of OCM, a crowd-sourced website which aims to provide users with a reliable and free point of reference for charging equipment locations worldwide, comes with its limitations:
  - The information is not comprehensive; the number of public charging points registered for the EU is approximately 30% less than what the European Alternative Fuels Observatory has reported.
  - The time lag between the date of operation of a station and its addition to the database may be larger than that present with other sources. This applies, too, to the removal of stations that are not operational anymore.
  - Data may be inaccurately classified by those entering it, either due to human error or the fact that documentation of fields and their definitions are non-exhaustive.
  - Regional biases may exist – those in certain regions may be more aware of the existence of the website and thus record more stations in their area compared to others.

Semi-structured interviews representing key stakeholder groups

- Five semi-structured interviews were conducted to understand the current state of charging infrastructure provision and what challenges and opportunities they see in its future development. The duration of the interviews varied from half an hour to an hour, and notes were taken manually in all cases except for one where the interview was transcribed. All interviews have been anonymized, but stakeholder groups represented include:
  - Research [50]
  - Consulting [16]
  - OEM [9]
  - Industry association for electricity [56]
  - Industry association for charging infrastructure [55]

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EUROPEAN PARKING ASSOCIATION
Positively promoting parking solutions for sustainable mobility

UPT
ERASMUS CENTRE FOR URBAN, PORT AND TRANSPORT ECONOMICS

The European Parking Association, founded in 1983, is the umbrella organisation for European parking associations. The national member associations represent the parking sector which is consisting of private companies and public bodies that are operating and managing on- and off-street parking structures and services. The associate members represent the supply industry that offers all related products and services concerned with parking. The EPA aims to facilitate cooperation between the professional parking organisations of different European countries, the exchange and mutual support of professional experience among members and may exert influence on measures and resolutions of the European Commission and other relevant international bodies relating to parking and urban mobility.

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