Public EV Charging in Europe: Market Dynamics and Consumer Perspectives

Final Report

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INTRODUCTION

The uptake of electric vehicles (EVs) brings opportunities in energy storage, sustainability, and the emergence of innovative providers and solutions. In 2024, the EU adopted reforms to electricity market legislation to enhance resilience and consumer-friendliness while promoting renewable energy integration.

This report summarises the outputs of a study to understand the market dynamics and consumer perspectives in the public charging market for electrified passenger vehicles in Europe. The sections of this summary are structured as follows:

- Current status in European charging infrastructure
- Perspectives of charge point operators and e-mobility service providers
- Consumer perspectives and needs
- European electric vehicle market outlook
- Charging infrastructure deployment in the EU
- Conclusions

EXECUTIVE SUMMARY AND POLICY RECOMMENDATIONS

CURRENT STATUS OF CHARGING OF EUROPEAN CHARGING TECHNOLOGY

Standardisation ensures that Battery Electric Vehicles (BEVs) and charging infrastructure are interoperable regardless of location or manufacturer which is critical to the user experience. The EU adopts a range of standards developed by the International Electrotechnical Commission (IEC) and the International Organisation for Standardisation (ISO) across a range of key domains that are critical to ensuring interoperability like charging modes, connector designs and communications standards.

IEC 61851 describes four modes of charging which are already well established. Mode 1 and Mode 2 refer to slow charging which takes places through conventional electrical sockets, with the latter using safety equipment built into the cable. These modes are expected to continue to decline as dedicated charging stations are widely deployed for AC charging (Mode 3) and DC charging (Mode 4). The EU uses select connector types from the global standard IEC 62196 such as Type2 connectors and CCS2. Technology capabilities are rapidly evolving globally, which creates potential interoperability challenges in cases where obsolete connector types are built into public charging stations, such as the CHAdeMO connectors.

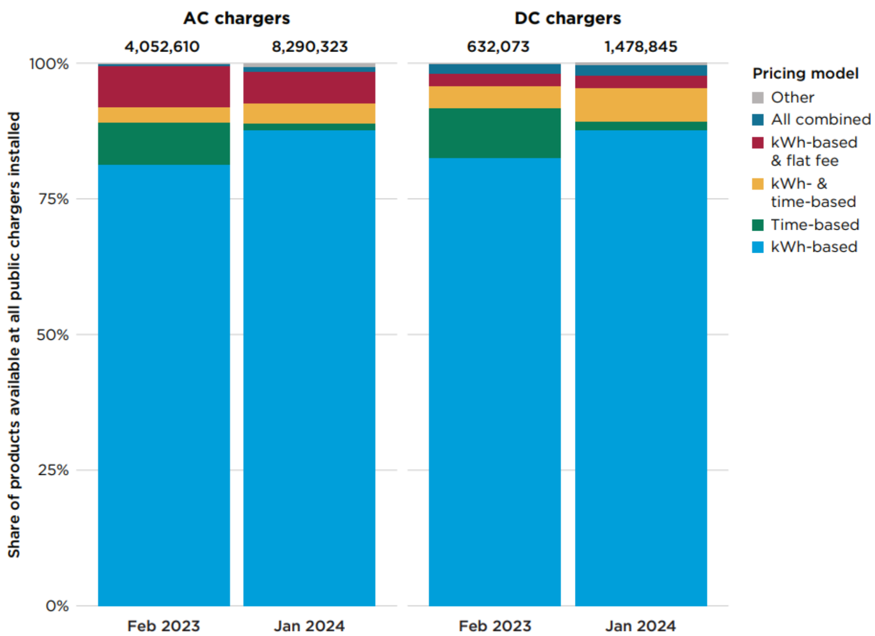
Communication standards, similar to connector standards are also continuing to evolve. ISO 15118 lays the foundation of communication between the vehicle and charging station, but improved functionality such as bidirectional charging and plug and charge create new data exchange requirements across parts of the communication chain (Charging stations, CPOs, eMSPs, DNOs and Grid operators). Plug and charge functionality enables automatic vehicle authentication and can mitigate common user frustrations, such as the need for multiple charging applications or charging cards specific to different charging providers.

PERSPECTIVES OF CPOS AND EMSPS

Charge Point Operators (CPOs) are responsible for managing and operating charging hardware, while eMobility Service Providers (eMSPs) focus on managing the digital end-customer services (e.g., access, payments, etc.). A company offering charging services can take one or both of these roles, but in Europe companies most commonly adopt the latter - a vertically integrated approach providing end-to-end services to users. Integrated charging providers typically adopt one of three main business models depending on their organisation's objectives, cost constraints, desired level of control in price-setting and involvement in overseeing charging operations. The Network Operator model, used by players like ChargePoint, involves selling hardware to site hosts and earning network fees from them to bill users and manage access, but the site host sets the final charging price. In the Owner Operator model, used by players like Tesla, the company owns the infrastructure, sets the prices, and relies on driver subscription fees and high charger utilisation for revenue. Finally, the emerging Charging-as-a-Service model sees companies like Virta offer turnkey solutions to site owners for a recurring subscription fee, removing the burdens of upfront cost and maintenance. The business model descriptions, price control, business risk and example companies are summarised in the figure below.

Business Models	Infra. owner	Revenue source	Example
Network Operator Model • Charging providers sell hardware (charge points) to site hosts and earn network fees from them to bill users and manage access. • The site host sets the final charging price.	Site owner	Site owner	chargepoint
Owner Operator Model • Charging providers own the infrastructure and set the prices, relying on driver subscription fees and high charger utilisation for revenue. • Site hosts benefit from access to charging but have no control over pricing	Charging company	Consumers	Tesla
Charging-As-A-Service (CAAS) • Charging providers offer a monthly subscription-based package to site owners that provides turnkey EV recharging solutions, with minimal upfront costs • Removes the burden of ownership and maintenance from the site host.	Charging company	Site owner	VIRTA

Fee structures for EV charging typically comprise of one or more of the following building blocks; a price per unit of energy in kWh that is also known as an energy based or volumetric pricing, a time-based price that is calculated based on the amount the electrified bay is occupied, and a flat fee for initiating charging sessions or subscription cost for utilising the service. A greater number of building blocks in the pricing structure for EV charging hinders transparency for end users while energy-based pricing alone is broadly the easiest for consumers to understand and allows them to estimate the cost of charging prior to initiating charging sessions. In 2024, approximately 90% of public charging stations in Europe use energy-based pricing alone while the remaining 10% use either one of the remaining pricing options or a combination of the options.



CPOs and eMSPs face many challenges, which not only have implications for their businesses but also hinder the transition to electrified mobility. The challenges relating to grid constraints are considered to be the most significant barrier to public charging infrastructure deployment. In many cases, grid upgrades are required to ensure adequate energy supply for EV charging, which can be costly and involve lengthy, complex and inconsistent processes across Member States which deters investment. In addition, as the energy and transport systems become increasingly integrated, grid system faults present a significant threat to charging providers' business cases due to increased downtime which reduces the opportunity to recuperate investments.

Strategic decisions among charging providers can also discourage healthy competition. For example, exclusive contracts or vertical integration between CPOs or eMSPs with upstream stakeholders such as Distribution Network Operators (DNOs) can limit site access for other charging providers and give priority to partner organisations. This challenge is particularly impactful in cases where the charging provider does not have the capacity to roll out infrastructure at pace. In addition to exclusionary challenges, a fast-changing fleet composition can also create uncertainties in determining the right mix of charging station types at sites which can negatively impact investment efficiency. This may result in the number or output rating of charging stations needing to be increased retrospectively unless future-proofing measures are accounted for during the planning phase.

CONSUMER PERSPECTIVES AND NEEDS

A range of decision-making criteria are used by consumers in relation to their charging preferences. Generally, more than half of consumers (55%) are estimated to prioritise convenience factors, such as access to the nearest charging station with the least waiting time and fastest charging rate. Consumers who prioritise convenience will often be willing to pay for the time they save. In contrast, 25% of consumers prioritise price. In these cases, drivers are willing to sacrifice time to charge at lower prices. Other factors are also relevant such as quality (10%), whereby drivers are willing to pay more or wait longer to be able to charge with renewable energy. Finally, consumers may prioritise brand loyalty (10%) and choose to earn or redeem points with select charging providers. These consumer decision-making criteria are summarised as follows.

Convenience can encompass a variety of factors in EV charging, such as working function, charging times and short or no waiting times due to use by other drivers. Faults at public infrastructure disproportionately impact users who do not have access to private charging solutions and reinforces a perception of unreliability that deters both current users and potential EV buyers. As users tend to prioritise fast and functional chargers over price, improving the operational reliability of the existing charging network must become a central focus for policymakers, operators and industry stakeholders alike.

Low operating costs are a key driver for users switching from conventional vehicles to EVs. A survey revealed that 91% of drivers who use private charging found their operational costs to be lower with an EV compared to an internal combustion engine (ICE) vehicle due to cheaper electricity rates available during the night. However, for drivers which relied on public charging, 28% of drivers found their operational costs to be the same for both vehicle types, while 15% found their operational costs to be higher with EVs. In addition to the level of pricing, consumers face challenges in adjacent areas:

1. **Price transparency:** While energy-based pricing is easiest for consumers to understand, rates can vary depending on whether the drivers utilise services of eMSPs or opt for ad hoc charging. For the latter, consumers find it particularly challenging to compare prices between charging providers and with eMSPs.
2. **Payment methods:** Charge cards and phone applications are common payment methods used in Europe. As of April 2023, the Alternative Fuels Infrastructure Regulation (AFIR) requires ad hoc payment options to be available through at least one widely used electronic payment instrument. This requirement is expected to tackle a range of payment related issues highlighted by a survey of European drivers. Key findings of the survey showed that 87% of respondents had to download a new app at least once to pay while 80% of drivers experienced payment problems due to connectivity issues.

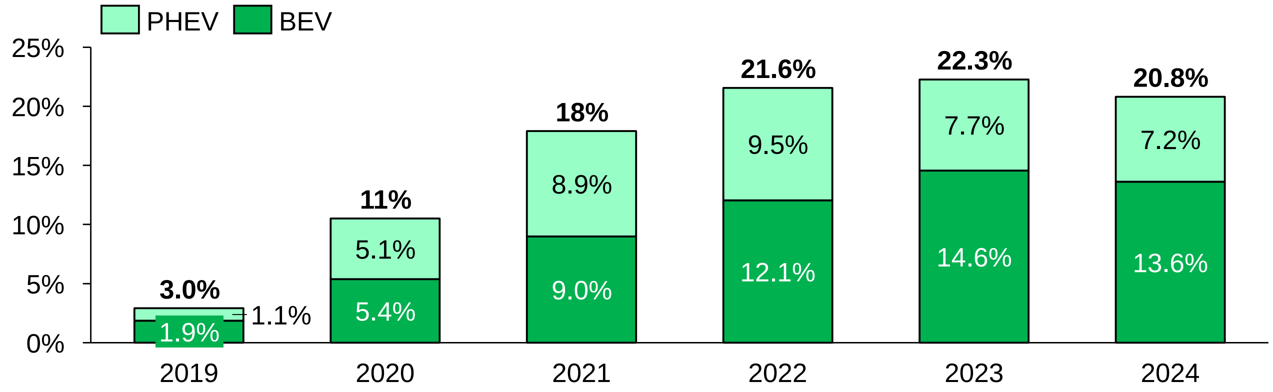
Energy source is another important consideration for EV drivers. The McKinsey Pulse survey which garnered responses from nearly 31 thousand mobility users including EV drivers and prospective EV buyers across 15 countries (EU & non-EU) found that 55% of respondents indicated the importance of renewable energy for charging. A further 25% indicated that it is a 'nice to have' but not essential. 70% of respondents indicated that they would be willing to pay a premium for charging with renewable energy. Despite the evidence in consumers' willingness to pay for charging with renewable energy, a survey by the European Alternative Fuels Observatory (EAFO) indicated that more than two thirds of drivers are unaware of the source of electricity for charging, which highlights a need for better transparency in not only pricing structures, but also the electricity source for consumers to make more informed decisions.

The accessibility constraints are highlighted by disabled users as significant barriers to use of EV charging. In a 2024 survey of over 6,500 UK based disabled drivers highlighted experiences of different issues relating to access of EV charging. The survey highlighted that 62% of the respondents' found issues with the surrounding area which restricted access due to lack of dropped kerbs, while almost half of respondents found issues relating to the charging cables being too heavy, too short or otherwise unsuitable. Other issues experienced by disabled users included the difficulties in reading the screen, the size and layout of the bay being unsuitable for wheelchair access and the payment or card mechanism being too high or difficult to use.

While AFIR mandates accessible charging, recent surveys suggest that many users continue to face exclusion due to a lack of accounting for their specific needs in the design of EV infrastructure.

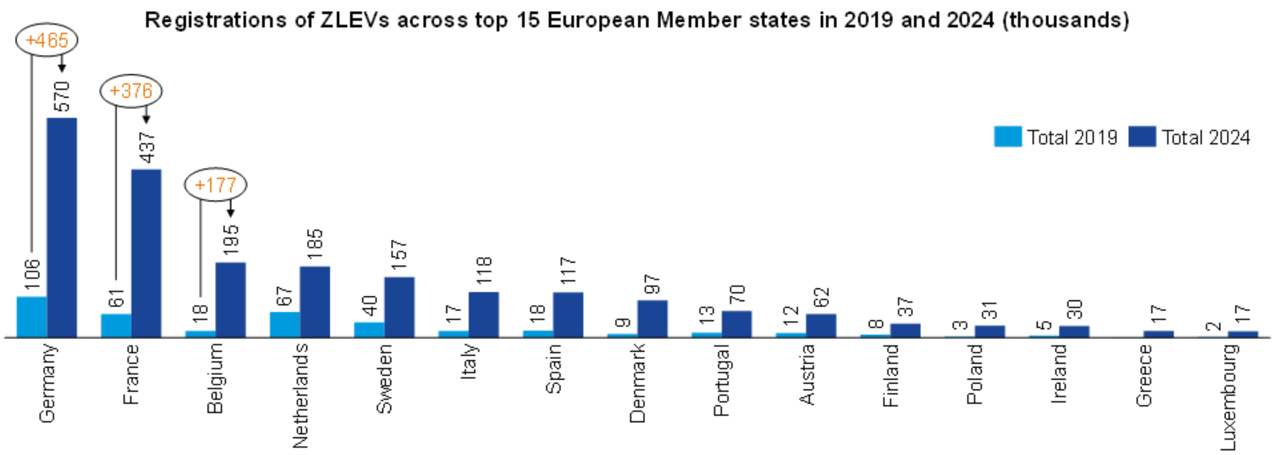
EUROPEAN EV MARKET OUTLOOK

Between 2019 and 2023, annual registrations of zero emission cars in Europe - including BEVs and Fuel Cell Electric Vehicles (FCEVs) - increased consistently, with 2023 volumes (~1.5 million units) nearly three times higher than in 2020 (~0.6 million units). Over the same period, the overall share of newly registered zero- and low-emission vehicles (ZLEVs) has drastically increased from just 3% in 2019 (1.9% BEVs, 1.1% PHEVs) to 22.3 in 2023 (14.6% BEVs, 7.7% PHEVs) as shown below.



However, the marginal contraction observed in 2024, with zero- and low-emission vehicles falling to a combined share of 20.8% (13.6% BEVs, 7.2% PHEVs), indicates an early inflection point in the rate of progress. This moderation may signal emerging structural barriers: weakening policy incentives in some Member States, lagging infrastructure in key markets, or a slowdown in early adopter demand. It also suggests that while the EU has achieved strong early-stage momentum, the transition from early to mass-market adoption is encountering friction.

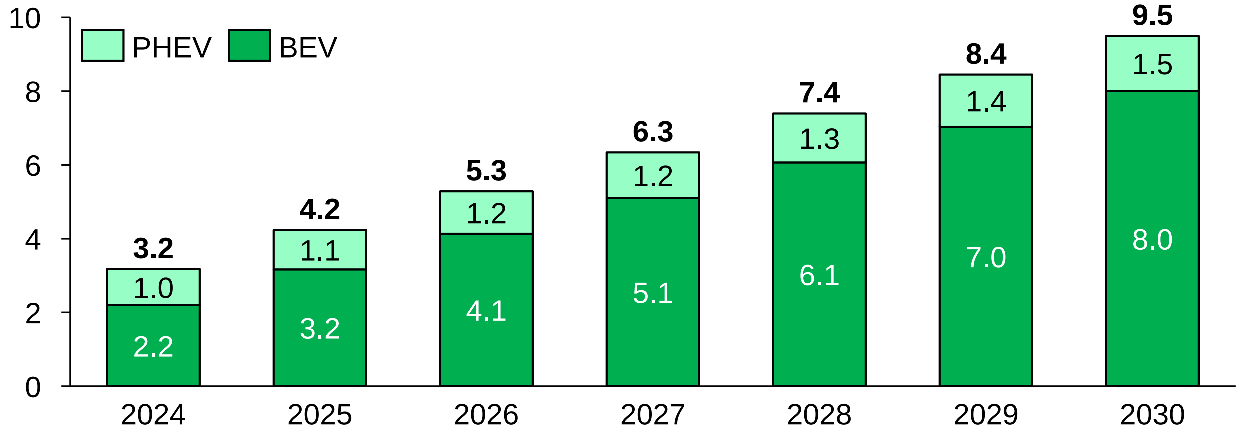
Geographical leaders in 2024 ZLEV registration volumes and growth in volumes since 2019 are Germany, France and Belgium. The top 15 Member states shown below capture 97% of total European ZLEV registrations in 2024.



In terms of overall vehicle fleet similar countries lead with Germany and France totaling 2.6 million and 1.9 million ZLEVs in their vehicle fleet. The Netherlands ranks third with 0.9 million while all three countries had 0.2 million ZLEVs in their fleet in 2019.

IEA EV outlook data forecasts have been reviewed to understand the projection of EV sales across Europe based on implemented and firmly planned government policies which are outlined by the Stated Policies Scenario (STEPS). Between 2024 and 2030, sales in Europe are projected to grow significantly, rising from approximately 3.18 million to 9.5 million annually. This represents a near tripling of total EV sales over the period, however, actual sales in the forecast are likely to be overstated given the EAFO numbers shown above for the same base year. PHEVs also see steady growth in absolute numbers, increasing from approximately 1 million units in 2024 to 1.5 million in 2030. However, their share of total EV sales declines as BEVs scale up more rapidly. FCEVs remain marginal throughout the period, with sales projected to reach only about 4,400 units by 2030.

Forecast of BEV and PHEV sales in Europe to 2030 (millions)

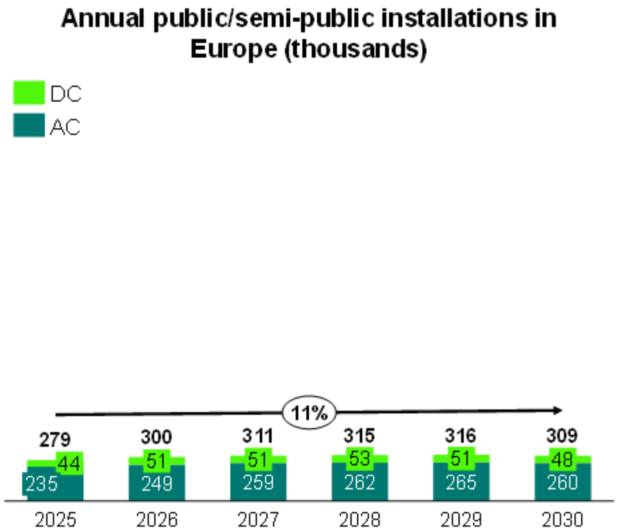


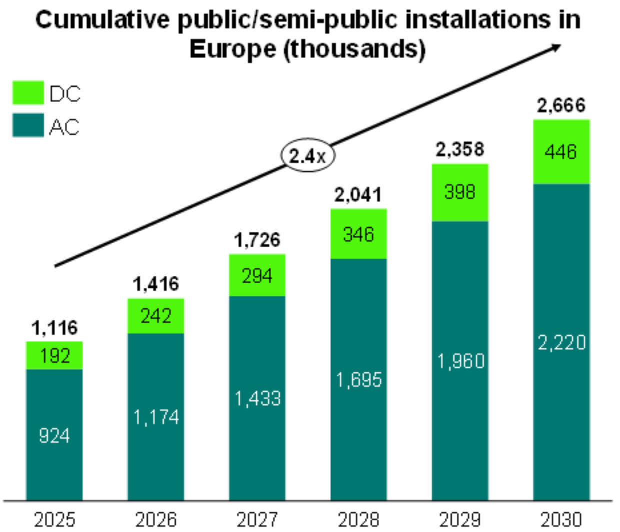
CHARGING INFRASTRUCTURE DEPLOYMENT IN THE EU

The EU's Alternative Fuels Infrastructure Regulation (AFIR) is part of the Fit for 55 package which aims to reduce net Greenhouse Gas emissions by 55% by 2030 with respect to emissions in 1990. It is a binding regulation which sets obligatory targets from 2024 on the rollout of recharging and refuelling infrastructure in two key parts: a distance-based target and a fleet-based target.

The distance-based target sets requirements for increasing power rating of charging pools (one or more charging stations) along every 60 km of the Trans-European Transport Network (TEN-T). The TEN-T network is Europe-wide and comprises of roads, rail lines, ports and airports designed to improve transport infrastructure and connectivity across the EU. In contrast, the fleet-based targets for installed charging capacity are based on the number of registered electrified vehicles across member states. From 2024, 1.3 kW of public charging capacity must be available per registered BEV, while 0.8 kW of public charging capacity must be available per registered PHEV. As of June 2025, most Member States (25) surpassed their mandated targets. France and Germany recorded the highest absolute deployment levels, each exceeding 5 million kW, followed by the Netherlands with over 3.5 million kW. All three demonstrated surpluses of more than 2 million kW relative to their respective AFIR obligations. Two Member States, Ireland, and Malta did not meet their 2024 fleet-based charging power output targets.

Between 2025 to 2030, the total volume of charging stations in Europe is expected to increase from 12.2 million to 35.4 million, showing a near tripling of overall volumes. Over 90% of the infrastructure share is expected to be for private charging over the forecast period. As shown below, annual public and semi-public infrastructure deployments are expected to grow marginally year on year from 0.28 million in 2025 to 0.31 million in 2030. On a cumulative basis, the available volume of public/semi-public infrastructure is expected to grow by a factor of 2.4x from 1.1 million to 2.7 million. AC charging infrastructure is expected to dominate future deployments with a share of approximately 83% from 2025 to 2030.





POLICY RECOMMENDATIONS

A range of policy recommendations have been formulated to address the challenges faced by CPOs and eMSPs and alleviate consumer concerns around convenience, payment and accessibility.

Policy recommendations	Detail
Continued support for incentives to support EV uptake and infrastructure deployment	• Some regions benefit from dense, high-speed networks, while others remain underserved, particularly in rural or economically disadvantaged areas • Non-financial incentives can be used temporarily in rural areas with low EV deployment and infrastructure availability to help reach a critical mass of EV uptake and provide a driver for CPOs and eMSPs to expand their offerings to such areas
Harmonise grid upgrading processes and energy billing for EV infrastructure across EU countries	• Capacity constraints are the biggest challenge for EV charging network operators in 2025 – a survey conducted with 300 full-time employees working in the EV charging industry revealed this as the top concern, with more than 90% of respondents expecting lack of grid capacity to hinder their growth over the next year • Complicating matters further is the variation in grid operator billing intervals across European countries. For instance, while Belgian DSOs use 10-minute billing periods, German operators rely on 15-minute intervals. • Discrepancies make it increasingly difficult for CPOs operating across borders to harmonise their operations and optimise grid fee management, as they must navigate diverse regulatory frameworks and compliance standards in each jurisdiction
Introduce transparent and publicly accessible information on the current and planned grid infrastructure for EV charging and stakeholder forums to address challenges for the 'hard to electrify' regions across the EU and ensure adequate coverage	• Lack of clarity involving the application procedure and/or competent authorities assessing the permit application, for example, varying definitions for what is considered a 'recharging station', sudden changes in responsible permitting body, and unpredictability for response times and final decisions

Policy recommendations	Detail
Enforce reliability standards for public chargers including uptime requirements, maintenance response times and clear fault reporting systems	• Charging station downtime influences not just the user experience by lowering the availability of functional charging stations, but it is also detrimental to CPO and eMSP business cases • Some issues encountered by users include unresponsible or unavailable screens, payment system failures, or vehicle-to-charger communication failures, network failures and broken connectors • With each CPO potentially employing different metrics and service expectations, even within the same country, this can complicate cross-border charging experiences and add to charging anxiety among potential new EV users
Strengthen enforcement of AFIR payment rules requiring all public chargers to offer clear, simple and universally accepted ad hoc payment options (e.g. contactless card payments)	• A lack of suitable payment methods at charging stations is widely cited as a consumer frustration, as it can result in users having to seek alternative stations, add unexpected delays, cause stress and create an overall negative perception of the EV charging experience • Surveys show that few users rely on a single method, and many have experienced problems such as failed transactions, poor connectivity, or being forced to download a new app at the point of use
Clearly communicate fines for overstaying at charging stations via signage or a digital mechanism (e.g. charging app). Where possible, operators of charging facilities should also ensure that the level of fines imposed are standardised	• Penalties, imposed by charging providers to consumers, for overstaying at charging stations are often not explicitly communicated to consumers or are unclear and, in some cases, have amounted to charging sessions incurring a cost of hundreds of Euros • Consumer concerns highlight not only a lack of transparency in the penalty mechanism, but they also view the fines as being disproportionate, which reinforces a need for regulatory intervention
Promote awareness raising and education aimed at consumers – improving awareness of pricing options, subscription benefits, payment methods and available support for new EV users	• A survey revealed that almost 30% of users who rely on public charging found their operational costs to be the same as operating a conventional vehicle while 15% found BEVs to be more expensive • Awareness of the pricing options and subscription benefits is likely to enable consumers to make more informed decisions and ensure the cost saving benefits of BEVs are fully leveraged
Consolidate pricing structures towards volumetric or energy-based pricing where feasible	• Energy-based pricing structures are most similar to the pricing mechanism of refuelling conventional vehicles, and they are therefore easiest for consumers to understand as opposed to time-based pricing or flat-fee structures • Combined pricing structures hinder transparency and create challenges for consumers to estimate the approximate cost of their charging session beforehand • The number of types of pricing structures should, where possible, be minimised and aligned with volumetric pricing which is already used by approximately 90% of charging stations in the EU
Promote inclusive infrastructure upgrades targeting priority user groups (disabled users, women, older adults), potentially supported by public-private partnerships	• A wide range of challenges are encountered by disabled users which fundamentally limit their ability to own and use BEVs. These challenges primarily relate to accessibility and use of public charging infrastructure, including lack of dropped kerbs, charging cables being too heavy, screens being difficult to read, payment mechanisms being too high etc

Policy recommendations	Detail
or accessibility improvement grants	• Surveys show that fewer women feel safe compared to men in the context of EV charging, citing reasons such as inadequate lighting or the risk of potential theft of exposed charging cables • In the UK there's been an introduction of a grant funding 75% of the costs for the installation of EV charge points in locations traditionally visited more frequently by women such as schools and nurseries
Ensure consistent, up to date and easily accessible information on the location and live status of electric chargers is provided to consumers	• Drivers without access to off-street/private parking often rely solely on public infrastructure to meet their charging needs • Inconsistencies have been identified in the information provided across charging point websites regarding how many charging points are available at each location, whether the charging point is a single or twin socket, and status of charger, which can all lead to confusion or inconvenience for consumers • More widespread information aimed at the public on the location and availability of charging points would assist in raising awareness amongst EV owners (and potential owners)

CONTENTS

LIST OF ACRONYMS

Term	Full Form
AC	Alternating Current
ACEA	European Automobile Manufacturers' Association
AFIR	Alternative Fuel Infrastructure Regulation
APS	Announced Pledges Scenario
BEV	Battery Electric Vehicle
CAGR	Compound Annual Growth Rate
CCS	Combined Charging Standard
CPO	Charge Point Operator
CSMS	Charging Station Management System
DC	Direct Current
DNO	Distribution Network Operator
DSO	Distribution Service Operator
EAFO	European Alternative Fuels Observatory
EB	European Bureau
EBRD	European Bank for Reconstruction and Development
EDF	Électricité de France
EIB	European Investment Bank
eMIP	eMobility Interoperation Protocol
EMS	Energy Management System
EMSP	E-Mobility Service Provider
EPBD	Energy Performance of Buildings Directive
EU	European Union
EV	Electric Vehicle
EVA	Electric Vehicle Association
EVSE	Electric Vehicle Supply Equipment
ICE	Internal Combustion Engine
IEA	International Energy Agency
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
LEV	Low Emission Vehicle
MS	Member States
MSP	Mobility Service Provider
NACS	North America Charging Standard
NOK	Norwegian Krone
NPF	National Policy Framework
OCHP	Open Clearing House Protocol
OCPI	Open Charge Point Interface
OCPP	Open Charge Point Protocol
OCSP	Online Certificate Status Protocol
OEM	Original Equipment Manufacturer
OICP	Open Intercharge Protocol
OSCP	Open Smart Charging Protocol
PHEV	Plug-in Hybrid Electric Vehicle
PKI	Public Key Infrastructure

Term	Full Form
PnC	Plug and Charge
RFID	Radio Frequency Identification
STEPS	Stated Policies Scenario
TEN-T	Trans-European Transport Network
TLS	Transport Layer Security
UK	United Kingdom
VAT	Value Added Tax
ZEV	Zero Emission Vehicle
ZLEV	Zero and Low Emission Vehicle

1. INTRODUCTION

Ricardo is pleased to deliver this study in response to the request for a research project titled '*Public EV Charging in Europe: Market Dynamics and Consumer Perspectives'* for the FIA European Bureau (FIA EB).

1.1 BACKGROUND

The uptake of electric vehicles (EVs) brings opportunities in energy storage, sustainability, and the emergence of innovative providers and solutions. In 2024, the EU adopted reforms to electricity market legislation to enhance resilience and consumer-friendliness while promoting renewable energy integration. In the transport sector, the Alternative Fuels Infrastructure Regulation (AFIR), which sets out charging infrastructure deployment targets for the EU, mandates transparent information at public charging stations and that users are offered multiple payment options.

This report presents research on the evolving charging market, the role of e-mobility service providers (eMSPs), and the application of the AFIR, to provide valuable insights into the current landscape and future developments. This work aligns with FIA EB's commitment to supporting sustainable and user-friendly mobility solutions.

European legislation currently sets the path to zero CO_2 emissions for new passenger cars in 2035, with intermediate targets for 2030 of 55% reduction in fleet wide CO_2 emissions compared to 2021 levels. For households with access to private off-street parking, the cheapest and most convenient method of charging will be home charging. However, for households without access to private off-street parking and for those consumers making longer journeys there will be a reliance on the public charging network. The focus of this research is on public charging for private passenger cars in Europe.

1.2 STUDY OBJECTIVES

The key objectives of this study are as follows:

1. To map out current experiences with charging infrastructure:
    - Including the analysis of available types of charging infrastructure, pricing models, interoperability, user experience, and challenges faced by both traditional charging point operators and emerging eMSPs
2. To assess factors affecting the market outlook for EV charging:
    - Including the assessment of factors such as the increasing adoption of EVs, the emergence of new business models, the evolving roles of eMSPs and their impact on traditional operators, and the level, evolution, and transparency of prices.
3. To investigate consumer perspective and needs in relation to public charging infrastructure and pricing:
    - Including consumer experience in accessing and using charging infrastructure, understanding pricing options, managing subscriptions, and leveraging smart charging features. The research should also explore factors such as convenience, accessibility, reliability, payment options, and customer support.
4. To provide a high level evaluation of charging infrastructure deployment in the EU:
    - Including an evaluation of the progress made in various countries, considering the availability and accessibility of charging infrastructure (both public and private), government policies, and incentives, and identify challenges in achieving comprehensive coverage.

1.3 STRUCTURE OF THIS REPORT

This report is structured as follows:

- Current status in European charging infrastructure (Section 2)
- Perspectives of charge point operators and e-mobility service providers (Section 3)
- Consumer perspectives and needs (Section 4)

- Electric vehicle market outlook (Section 5)
- Charging infrastructure deployment in the EU (Section 6)
- Conclusions (Section 7)

2. CURRENT STATUS IN EUROPEAN CHARGING INFRASTRUCTURE

2.1 INTRODUCTION

The current technology landscape for EV charging is complex and continues to evolve, with increasing capabilities of both vehicle-side and infrastructure-side technology. Charging stations are often categorised based on power output, charging speed and connector types. Unlike conventional vehicles which utilise standardised and globally aligned fuel nozzles, the competitive landscape in EV charging has led significant regional variation in the technical specifications of charging systems, especially connector types. However, consumer expectations lay the foundation for building regionally aligned standards that seek to ensure interoperability of charging technology. This section provides an overview of the current technology status and standards for charging stations in Europe.

2.2 STANDARDS AND INTEROPERABILITY

Global charging standards are defined to address consumer needs such as safety, reliability and interoperability issues of the EV market. The International Electrotechnical Commission (IEC) defines global standards for electrical technologies including EV charging infrastructure types, covering power delivery, connector types, communication protocols and safety.

Adoption of standards in Europe

Table 2-1 below shows the key standards which apply across different aspects of EV charging and highlight the relevance to the European market which are expanded upon in the following sections.

Table 2-1: Key standards and across charging domains and their implementation within the EU

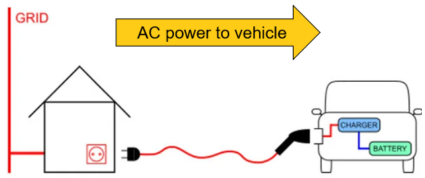
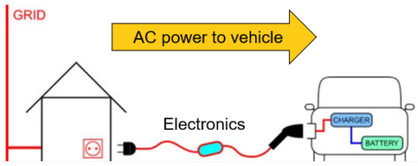
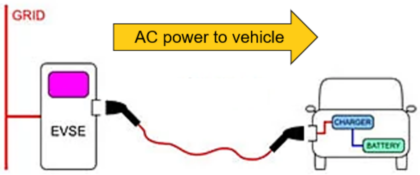
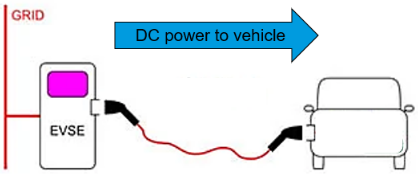
Domain	Global Standard	Standard implementation in the EU
Power delivery modes	IEC 61851 (Modes 1–4)	Fully adopts IEC
Connectors (General requirements)	IEC 62196-1	EU enforces specific connectors
Connectors for AC (alternating current) charging	IEC 62196-2	EU enforces specific connectors
Connectors for DC (direct current) charging	IEC 62196-3	EU enforces specific connectors
Communication	Various protocols depending on the data exchange requirements and stakeholders involved, explored further in this section	Key standards in Europe include ISO 15118, Open charge point protocol and open smart charging protocol

IEC 61851 and IEC 62196 ensure safety and standardisation of EV charging and are known to be the backbone of the industry (Morek, 2024) (Paulraj, 2019). IEC 61851-1 defines four charging modes that categorise power delivery, protection installation and communication/control of charging systems. IEC 62196-2 categorises different socket outlets to deliver power from the charging station to the vehicle for AC charging stations while IEC 62196-3 performs the same function for DC charging stations.

IEC 61851: Charging mode definitions

Table 2-2 below shows a high-level overview of the charging mode categories defined by IEC 61851

Table 2-2: Overview of Mode 1-4 charging per standard IEC 61851-1

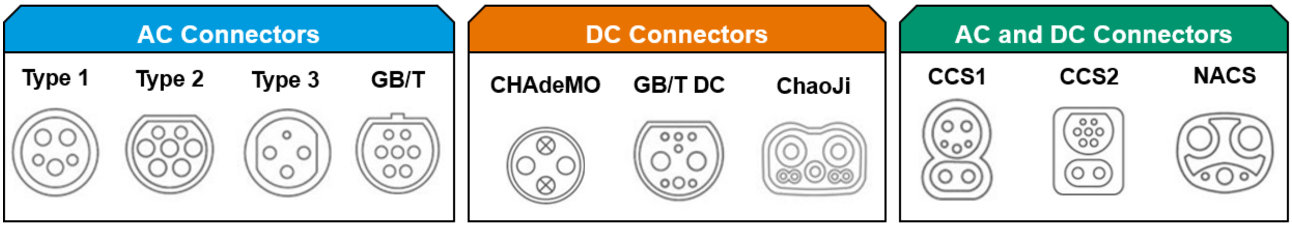
Mode	Description	Diagram (Pandžić, 2019)
Mode 1	• AC charging in which an electrical outlet charges the vehicle without electrical safety equipment • Mode 1 charging is typically limited to 2 kW but it is not recommended due to the safety risks which stem from overvoltage and overload (Eracharge, 2024)	
Mode 2	• AC charging in which an electrical outlet charges the vehicle with electrical safety equipment • Mode 2 charging is limited to low power due to outlet limitations. It is often used in emergencies or as an interim solution until a dedicated charger is installed	
Mode 3	• AC charging which takes place through a dedicated EV charging station at power levels typically between 7 kW to 22 kW • These charging stations can be either tethered, in which the cable is fixed at the charging station side or socketed, in which the charging cable is detachable at both ends	
Mode 4	• DC charging station power outputs typically range between 50 kW to 350 kW based on charging station specifications most widespread today • Recent developments in mode 4 charging include smaller form factors for stations rated at 30 to 50 kW (Electrek, 2025) and 400 kW+ (Automotive News Europe, 2025)	

Modes 1 and 2 are typically used for long stay public charging or private charging use cases, whereas Mode 3 can be used in either private or public/semi-public charging use cases. Currently Mode 4 is exclusively used for public/semi-public use cases. A key caveat for charging with Modes 1-3 is that charging power is limited to the rating of the lower-rated component; a vehicle with a 22 kW on-board charger connected to a 2.4 kW Mode 2 charger will charge at 2.4 kW, whereas a vehicle with an 11 kW on-board charger connected to a 7 kW Mode 3 AC charger will only charge at 7 kW. Hence, commercialising higher power mode 4 charging requires technological advancements in infrastructure to keep pace with vehicle developments and vice versa.

AC and DC charging connectors: IEC 62196

Various charging connector types are supported by Battery Electric Vehicles (BEVs) available today and the landscape for charging connectors continues to evolve with the improvements in their technical capabilities. Figure 2-1 below shows the types of charging connectors for AC and DC charging, including connector types that can be used for charging with AC or DC.

Figure 2-1: Overview of charging connector types for AC, DC and combined charging



Source: (S&P Global, 2022)

Early-stage fragmentation, competing regional connector designs pushed by developers and vehicle OEMs and the unique power and technology requirements of each region result in a range of connector designs as shown above[1]. Table 2-3 below describes per connector type the specific IEC standard section, relevance of each connector by region and the technology outlook.

Table 2-3: Overview of charging connectors including standards, key markets and technology outlook.

AC/DC	Type	Relevance to IEC standard	Key market	Technology outlook	Comments
AC	Type 1	IEC 62196-2	US, Japan	Widespread	Type 1 is generally not relevant to the European market with the exception of legacy infrastructure
AC	Type 2	IEC 62196-2	EU, US	Widespread	Type 2 or the Mennekes standard is capable of charging at single or three phase
AC	Type 3	IEC 62196-2	EU	Phasing out	Only used in some European countries but phasing out due to replacement by Type 2 connectors (Renault, 2020)
AC	GB/T	IEC 62196-2	China	Widespread	Expected to remain widespread
DC	CHAdeMO	IEC 62196-3	Japan, EU	Phasing out	ChaoJi is expected to replace CHAdeMO and GB/T. It is capable of charging speeds up to 1.2 MW and undergoing development. The standard could be backwards compatible with CCS for use in the European market (CHAdeMO, 2023)
DC	GB/T DC	IEC 62196-3	China	Phasing out	
DC	ChaoJi	Aiming to be included in international standards	Japan, China	Planned	
AC/DC	CCS1	IEC 62196-3	US	Widespread	Type 1 AC connectors are paired with two DC pins
AC/DC	CCS2	IEC 62196-3	EU	Widespread	Type 2 AC connectors are paired with two DC pins
AC/DC	North America Charging Standard (NACS)	Not currently relevant to IEC global standards, but compatible with CCS data	US	Phasing in	Standard developed by Tesla with the aim of being a future-proof standard capable of charging up to 1 MW. Currently 15,000+ NACS charging stations exist with support from over 11 vehicle and an

[1] Other connector designs are also under development, such as the Megawatt Charging Standard which is currently capable of charging at 3.75 MW. It is not featured above due to its focus on charging heavy duty vehicles with larger batteries for long-haul use cases.

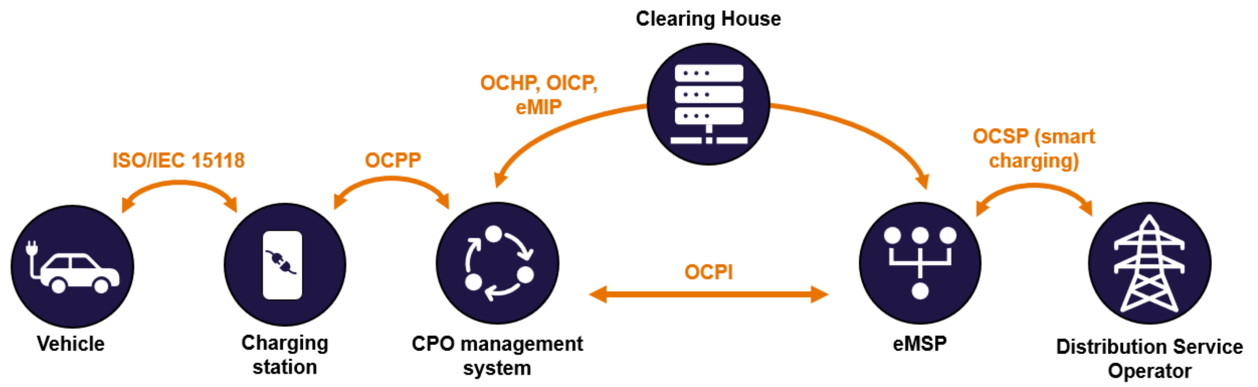
AC/DC	Type	Relevance to IEC standard	Key market	Technology outlook	Comments
		exchange standards			additional 9 OEMs expected to support in the future

Vehicle models and infrastructure supporting charging connectors which are being phased out create interoperability challenges unless backwards compatibility options are available. Vehicle OEMs such as Tesla navigate this by providing adaptors to enable compatibility between vehicle models that support new connectors and infrastructure which are fixed with older connectors (Tesla, 2025).

Communication standards

Communication protocols enable data exchange in the EV charging ecosystem for a variety of functions. These include ensuring interoperability, securely handling sensitive data for billing purposes, monitoring and optimising charging events while mitigating risks, and ensuring seamless transaction processes for users. Figure 2-2 adapted from (Klapwijk & Driessen, 2017) and (Tridens Technology, 2025) shows common charging standards between parts of the EV charging communication chain from the vehicle to the Distribution Service Operator (DSO). These protocols are investigated in further detail below.

Figure 2-2: Commonly used charging standards which govern data exchange between parts of the EV charging communication chain. OCPP: Open Charge Point Protocol, OCHP: Open Clearing House Protocol, OICP: Open Intercharge Protocol, eMIP: eMobility Interoperation Protocol, OCPI: Open Charge Point Interface, OCSP: Open Smart Charging



ISO 15118

ISO 15118 is an international standard which aims to standardise charging communications between the vehicle and charging stations. The standard was jointly developed by the International Organisation for Standardization and IEC in 2010 but continues to be developed further (EVConnect, 2024). Recent updates to the charging standard have focussed on enabling smart charging, vehicle to grid and Plug and Charge (PnC).

Open Charge Point Protocol (OCPP)

Open Charge Point Protocol (OCPP) is an open standard communication protocol developed by the Open Charge Alliance which defines interactions between EV charging stations and a central management system to facilitate security, transactions and diagnostics. Of the three versions available today, OCPP 1.6 released in 2016 offered a uniform approach for communications. OCPP 2.0.1 was released in 2020 with additional features such as improved transaction handling, added security and support for ISO 15118. It was approved as an IEC standard (IEC 63584) in 2024 and is expected to supersede version 1.6 as the industry standard for charging station-to-CMS data exchange (Open Charge Alliance, 2025). OCPP 2.5 was released in 2025 and is designed for more efficient and user-friendly charging while being compatible with the application logic for OCPP 2.0.1. Notable changes include support for ISO 15118-20 with bidirectional power transfer.

Roaming Protocols

Roaming protocols define operations between CPOs and eMSPs and provide end users information on charging stations across other networks using the same standard. There are four main roaming protocols which enable data exchange between these stakeholders; Open Charge Point Interface (OCPI), Open Intercharge Protocol (OICP), Open Clearing House Protocol (OCHP) and eMobility Interoperation Protocol (eMIP). In general, these standards support a range of use cases, including, access to charge point information, authorisation of charging sessions, sharing tariff information and enabling app-based charging (GreenFlux, 2022). OCPI is known to be the most widely used roaming protocol due to its relatively more comprehensive coverage of features as shown in Table 2-4 below (ChargeLab, 2023).

Table 2-4: Comparison of features of available roaming protocols (Green: feature available, Red: feature not available) (GreenFlux, 2022)

Features	OCPI	OICP	OCHP	EMIP
Hub roaming	Green	Green	Green	Green
Peer-to-peer roaming	Green	Red	Green	Green
Providing charge point information	Green	Green	Red	Green
Charge point search	Red	Red	Red	Green
Authorising sessions	Green	Green	Green	Green
Reservations	Green	Green	Red	Green
Remove start/stop	Green	Green	Green	Green
Session information	Green	Green	Green	Red
Ad-hoc payments	Red	Green	Red	Red
Billing	Green	Green	Green	Green
Smart charging	Green	Red	Red	Red
Calibration law support[2]	Green	Green	Red	Red
Platform monitoring	Green	Red	Red	Green
Communication	Real-time	Real-time	Asynchronous	Real-time

Smart and bidirectional charging

Smart charging capability varies the charging rate based on parameters such as grid demand, electricity prices and renewable energy availability. Conversely, bidirectional charging offers energy from EV batteries for grid services like frequency control and demand side management. Recent updates to ISO 15118 are expected to enable smart and bidirectional charging between the vehicle and infrastructure. However, coordination with Distribution Network Operators (DNOs) through complementary protocols such as the Open Smart Charging Protocol (OSCP) is necessary to allow DNOs to evaluate energy availability and respond to CPO requests for energy. Additionally, the protocol allows CPOs to relinquish unused capacity back to the DNO to allow other CPOs to use the available capacity.

Plug and Charge

Plug and Charge (PnC) functionality featured in ISO 15118 aims to simplify the EV charging process by automating authentication and payment stages without the need for identification through RFID cards (Radio Frequency Identification), debit or credit cards and payment applications. The "plug and go" concept makes charging more convenient by removing barriers to make the charging experience more comparable to refuelling a conventional vehicle. This relies on a robust security framework known as the Public Key

[2] Calibration law or measurement law was initially applied to gasoline pumps and other measuring devices to provide a detailed breakdown of prices and protect consumers from being overcharged. The law has been adapted to the EV market to ensure price transparency.

Infrastructure (PKI) which enables self-authorisation of vehicles upon plugging into charging stations. The PKI involves issuing digital certificates to authenticate the identities of battery electric vehicles (BEVs), charging stations and backend systems. This places stringent security requirements for backend systems for safe data exchange (CharIN, 2022). There are seven steps to initiating charging with PnC, Figure 2-3 below shows the initial two steps for authentication in which the vehicle initiates a Transport Layer Security (TLS) connection and presents a list of certificates to the charging station. The certificates are sent back to the vehicle with their Online Certificate Status Protocol (OCSP) information to validate the process known as the TLS handshake.

Figure 2-3: Initial TLS handshake authorisation of certificates for PnC

Figure 2-4 below shows steps three to seven for initiating PnC after the initial authorisation. The eMobility Account Identifier (eMAID) is a unique identifier assigned by the MSP which indicates an active subscription held by the EV owner for billing purposes and must be verified prior to each charging event. The charging session commences provided that the Charging Station Management System (CSMS) validates the eMAID with the eMSP and the certificates with the OCSP responder as shown below.

Figure 2-4: Information exchange which takes place after initial authorisation for PnC

PnC is undergoing continual development and is in its early-stage implementation phase in Europe. In 2024, Allego shared its plans to roll out PnC across over 34,000 charging stations (Electric Drives, 2024). By June 2025, the company has launched the functionality across 5,000 fast and ultra-fast charging stations (Lewis, 2025).

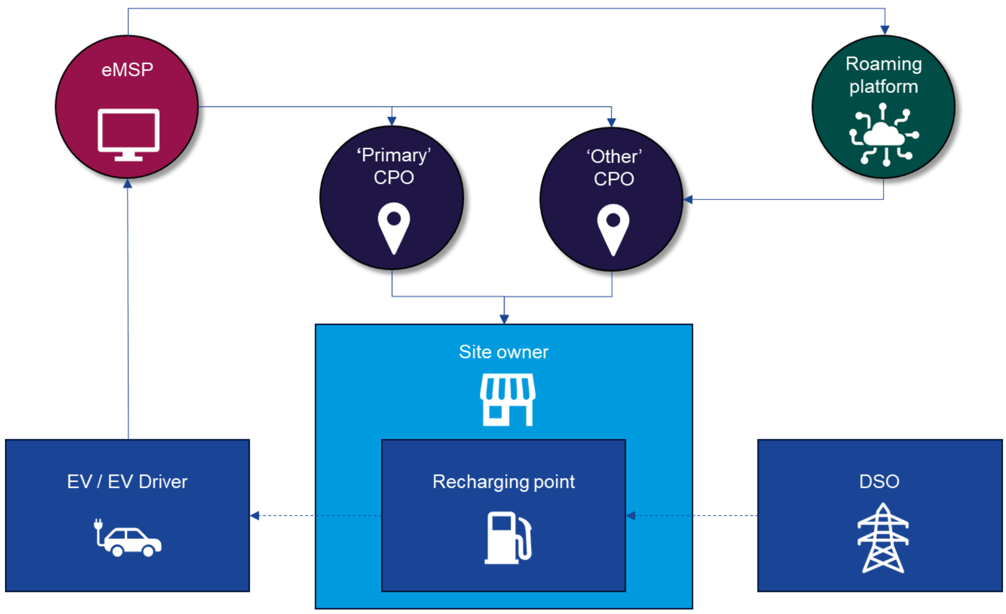
3. PERSPECTIVES OF CHARGEPOINT OPERATORS AND E-MOBILITY SERVICE PROVIDERS

3.1 INTRODUCTION

The most direct participants in the public EV recharging ecosystem are Charge Point Operators (CPOs) and eMobility Service Providers (eMSPs). CPOs are conventionally responsible for managing and operating charging hardware, while eMSPs focus on managing the digital end-customer services (e.g., access, payments, etc.). This section focuses on the perspectives of CPOs and eMSPs as the players engaging most directly with the consumer charging experience.

In addition to these direct participants, there is also a broader ecosystem of players such as EV manufacturers (OEMs), roaming platforms, site owners, energy providers (including DSOs), and regulatory bodies including local authorities. These players are relevant either because they provide complementary products or because they are in a position of control over where and how recharging points can be installed. The relationships between these players are shown in Figure 3-1 below.

Figure 3-1: EV recharging ecosystem, key market players



Source: Ricardo adaptation of Fig 3 from (CRA, 2023)

A range of different 'business models' are present for CPOs and eMSPs, and the EV recharging ecosystem is evolving rapidly. This section discusses the business models used in Europe, typical fee structures for end users, and the types of challenges faced.

3.2 BUSINESS MODELS

There are many factors which combine to form the 'business model' of a company. CPOs and eMSPs generally have one of two origin stories which help to understand their business model; pure players focus exclusively on EV charging, while new entrants hold established positions in adjacent sectors and diversify into EV charging, such as oil and gas companies, automotive manufacturers, and electricity utilities companies. Each entrant in the second category holds a unique advantage over pure players. Oil and gas companies have access to land at fuel stations to host infrastructure which often includes amenities, whilst automotive manufacturers have access to vehicle data and electric utilities companies have partial control over electricity prices (ICCT, 2025).

The role that a company adopts in the charging market is an important element of the business model. Some players have decided to only focus on one side of the EV recharging operation (CPO or eMSP). This is mostly the case for eMSPs given the lower investment needed to operate solely as a software company: ChargeMap and Plugsurfing provide pertinent pureplay success stories, while most vehicle OEMs provide their own in-house eMSP. However, most companies in Europe have adopted an integrated approach where one company plays the role of both the CPO and the eMSP. Given the higher growth of companies adopting this approach, this model is set to become even more prevalent in future (CRA, 2023). This is important from a competition perspective as, according to the Alternative Fuels Infrastructure Regulation (EU) 2023/1804, an integrated company is not allowed to discriminate on price against other eMSPs visa vis its own integrated eMSP.

Even within this integrated approach, different business models exist which vary in their objectives, cost constraints, desired level of control in price-setting, and willingness to manage charging operations (Yong, Tan, Khorasany, & Razzaghi, 2023). Notable business models for integrated companies are shown below.

Network operator model

In this model, a company would adopt both CPO and eMSP roles and generate revenue (a) by selling charge point hardware, and (b) through network fees paid by site hosts to manage the billing and access to charge points. However, the site host decides on the pricing terms, and so the company has no control of the price paid by consumers. The priority of the network operator is therefore to expand their operations to many sites to make it more attractive for consumers (who want to benefit from using the same billing service across many locations) and to generate recurring revenue from many sites to manage access and billing. It typically expands by either paying sites to place the company's charger, particularly when external/government funding is available or where the site is seen as important for consumer coverage, or through negotiating revenue sharing agreements. An example operating within the EU would be ChargePoint.

Owner operator model

In this model, a company again adopts both CPO and eMSP roles, but instead of selling the hardware, it supplies/owns the infrastructure and provides the back-end networking and billing capabilities on top. Importantly, they therefore determine the fees for use. The primary source of income is the monthly subscription fees that EV drivers pay to the company, regardless of how much they charge their vehicle. The company typically offers a reduced price for charging to monthly subscribers compared to the public, so that they can attract new users. However, since the company has large fixed costs and doesn't have a steady stream of revenue from site owners, they are more dependent on the utilisation of their charge points to generate a return on their investment. Tesla is one such example of a company operating this model.

Charging-as-a-service

In this emerging business model, a company offers a subscription-based package that provides turnkey EV recharging solutions with minimal upfront purchasing costs. The site owner pays a monthly subscription fee over a fixed term instead of all upfront costs at once, while also removing the burden of ownership and maintenance from the recharging host. eMSP services can be layered on top to offer an even more complete solution - Virta is one of the major players focusing on recharging as a service, and is one of the fastest-growing EV recharging platforms in the EU, operating in over 35 countries with over 690,000 public charging points.[3]

Fee structures

The building blocks of fee structures for EV charging largely depends on the entity which has control for price setting and their objective for the provision of charging solutions. Infrastructure owners are likely to prioritise one of the following:

1. **No fee:** charging sessions may be offered for customers solely as an amenity, whereby the value is derived from the alternative revenue generation sources such higher sales at destinations like malls or to enhance corporate branding. In this case, charging providers are likely to charge no fee for users of EV charging.
2. **Nominal fee:** charging fees may be moderate to recoup operational and installation costs. In some cases, these may also account for fluctuations in demand or electricity price spikes.
3. **Profit centred:** charging fees may be designed to help the owners profit from providing charging services. The pricing structure is meticulously planned through various options to enhance the business case.

While the actual charging rates are largely a function of grid conditions and how energy is priced by utilities, there are three basic building blocks for the pricing structures developed by charging providers to EV users:

[3] EV charging software | Virta

1. **Volumetric or energy-based pricing:** charging fees are calculated based on the amount of energy transferred to the vehicle in kWh. This is a commonly used approach, and most analogous to refuelling a conventional vehicle with litres of gasoline or diesel.
2. **Time-based pricing**: charging fees are calculated based on the time spent at the charging station once plugged in. In some instances, there may be separate charges for occupancy of the bay after the charging session has been completed.
3. **Flat fee**: charging fees are fixed and independent of energy transferred or time spent at the bay. This fee can be per session, a monthly or annual subscription but is typically used in conjunction with at least one of the other pricing mechanisms.

Table 3-1 below shows the variety in the business models adopted by companies in EV charging and the correlation to fee structures charged to end users

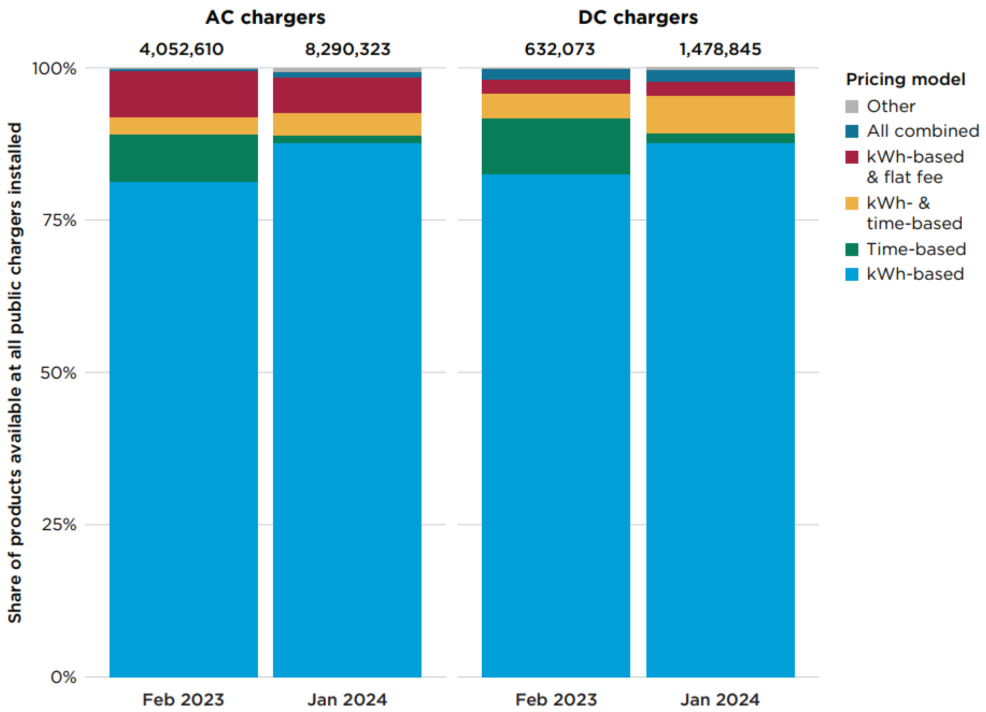
Table 3-1: Business models and fee structures deployed by global charging providers.

Charging provider	Region of Operation	Business Model	Fee structure
Chargefox	Australia	Network operator	Set by station operators
TGood	China	Owner operator	Volumetric fee
StarCharge	China	Network operator	Set by station operators
State Grid	China	Owner operator	Volumetric fee
E.ON	Europe, UK	Owner operator	Volumetric or volumetric fee + time-based
Fastned	Germany/Netherlands	Owner operator	Volumetric or volumetric fee + flat fee
Clever	Germany	Owner operator	Volumetric fee
IZIVIA	France	Owner operator	Flat fee + time-based
ESB eCars	Ireland	Owner operator	Flat fee + volumetric fee
KEPCO	South Korea	Owner operator	Volumetric fee
Chargepoint	North America, Europe, UK, Middle East,	Network operator	Set by station operators
Tesla	Europe, UK, North America, Asia, Middle East	Owner operator	Volumetric for Tesla drivers, Flat fee + Volumetric for non-Tesla drivers
BP Pulse	UK/Europe	Owner operator	Flat fee + volumetric fee
ChargeYourCar	UK	Network operator	Set by station operators
Blink	USA	Various	Pricing dependent on state rules: Volumetric or time-based or fixed DC charging costs
EVGo	USA	Owner operator	Time based or Flat fee + time based
Virta	EU	Charging-as-a-service	Flat fee + volumetric fee

Sources: (Yong, Tan, Khorasany, & Razzaghi, 2023; Chargepoint, n.d.; Tesla, n.d.)

The table shows the prominence of volumetric pricing, especially in European countries which all use volumetric pricing, often in combination with flat fees. Figure 3-2 describes the share of public AC and DC charging solutions in Europe which use the described pricing mechanisms in 2023 and 2024.

Figure 3-2: Share of pricing models in Europe for AC and DC charging in February 2023 and January 2024



Source: (ZEV Alliance, 2025)

Across both station types, the share of kWh-based pricing grows from approximately 80% in Feb 2023 to just under 90% in Jan 2024. Notably, pricing mechanisms in the “other” and “time-based” category represent up to only 5% of the mechanisms used in 2024. As all other mechanisms include an energy component, up to 95% of pricing mechanisms in Europe already include a volumetric component of pricing charged to consumers. Reducing the complexity of charging price structures creates significant ease for consumers to understand the prices before charging sessions are initiated, as further investigated in section 4.2.

Charging Tariffs

Unpredictability of demand for public charging stations cause cost burden on the charging provider which impacts their business model. Tariff structures must be designed by the charging provider to enable a healthy business case while encouraging positive charging behaviours, such as charging at times of high availability of renewable energy and low demand to avoid stress on the grid. Drivers who rely on public recharging can rarely access cheaper off-peak or dynamic electricity rates, as these rates are often not available to them and tend to be tailored to home recharging. This can lead to public recharging being less attractive, negatively impacting EV affordability for users who rely on on-street recharging. For example, in Ireland off-peak home recharging rates are almost four times lower than average public recharging rates. In contrast, Portugal has a well-developed public smart recharging system with a market design that encourages off-peak recharging (on average, Portuguese EV drivers can save €0.06/kWh by recharging during cheaper times at public stations) (CRA, 2023). There are various strategies that can be used to implement dynamic pricing as described in Table 3-2 below.

Table 3-2: Types of tariff structures for the implementation of dynamic pricing strategies

Tariff	Description	Challenge
Time of Use (TOU)	TOU rates offer different electricity tariffs according to the time of the day to encourage end users to charge vehicles during hours in which electricity consumption is typically low. Rates are often segmented by off-peak, mid-peak and	A potential downside of this approach is the simultaneous charging of a high number of vehicles at off-peak hours, inadvertently creating an electricity demand peak.

Tariff	Description	Challenge
	on-peak prices and aim to shift charging activity to off-peak hours.	
Critical Peak Pricing (CPP)	Critical Peak Pricing (CPP) tariffs are similar to TOU tariffs but rather than relying on historic electricity demand data to set charging prices, these are based on the current grid conditions and predictions of electricity demand.	While this strategy may avoid creating peaks in demand during off-peak hours, the price fluctuations are announced in a shorter notice period.
Peak Time Rebate (PTR)	Peak Time Rebate pricing rewards end users for reducing their electricity consumption at peak times rather than penalising them for charging at times of high demand as per the previously described methods. This approach can gain potential buy in from EV drivers by presenting an opportunity for demand minimisation rather than a penalty for adding demand to the grid.	This strategy requires charging operators to produce a customer baseline load estimation for the tariff scheme which adds time and cost. The accuracy of the estimation will also impact the business case for the charging provider implementing the PTR approach.
Real-Time Pricing (RTP)	In RTP schemes, pricing is adjusted in small intervals to more accurately mirror the current market conditions and reflect current electricity costs.	Quickly changing prices may frustrate consumers and create barriers to understanding the prices for charging prior to initiating charging sessions.

One key factor which may limit the type of tariff that can be provided is the availability of smart meters which varies by country in Europe. For example, the Nordic region has a higher share of smart meters which facilitates the option for charging providers to deploy the dynamic pricing tariffs described above. It is estimated that 84% of tariffs in Norway are based on dynamic pricing. On the other hand the deployment of smart meters in Germany is relatively slower, which results in 71% of users who are charged a standard flat rate for electricity (Yong, Tan, Khorasany, & Razzaghi, 2023).

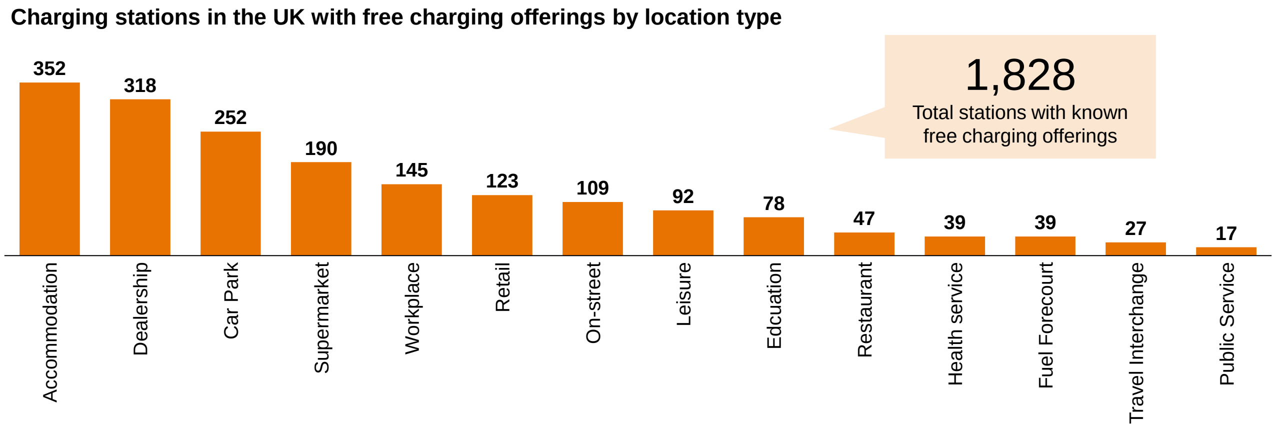
Stakeholder dynamics in pricing

Traditionally, large integrated players such as Ionity, Allego and Recharge have performed their own eMSP role by providing mobile applications, subscription models and customer services to users. However, the services provided by these companies remained limited to their own networks which does not promote full transparency of options available to users for charging. eMSPs can partner with a wide range of CPOs to provide drivers access to a large network through a single platform which is known as roaming. This allows eMSPs to equip drivers with critical up-to-date information of a large network of charging stations such as location, availability, specifications, pricing while also ensuring payment methods are streamlined across their network. The benefit to CPOs is the increased utilisation of their charging stations through visibility to drivers across eMSP networks. The offering is made available by the eMSP through a subscription and removes the need for multiple apps, time spent on web-based payments and carrying multiple charging cards for different CPOs, as is required with ad-hoc charging. However, in addition to the subscription price, eMSPs also determine their own pricing rates per kWh which may be aligned across their entire network or aligned across the CPOs on their network. Depending on the region and the type of charging station, the price offered by eMSPs may be higher than CPO ad hoc charging by as much as 12 cents per kWh (ZEV Alliance, 2025). However, given the lack of robust ad hoc price data, consumers are generally unable to compare eMSP prices to ad hoc prices.

Unique and emerging business strategies

Various players in the EV charging market have experimented with unique offering to attract customers. Free public charging is a commonly used approach but can often have differences in the way it is implemented. Tesla, with its unique position as both a vehicle OEM and a CPO, offered free and unlimited access to its supercharger network for the Model S, Model X and Model 3 until around 2020. It has relaunched the scheme in Europe for 2024 and 2025 to improve its vehicle sales, which is the aim of its free charging offering (Electrek, 2021). Volta also used a similar offering whereby free DC charging was offered to users for the first 30 minutes upon initiating charging sessions. This was made possible by accumulating revenue from advertising for other brands on the digital screens of Volta's DC charging hardware at suitable sites with good visibility to the public. After being acquired by Shell Recharge in 2023, the company has continued to refine this offering through software solutions like Volta Vision, whereby the contextually relevant ads are shown to consumers (Hiken, 2025). Figure 3-3 below shows the number of UK charging stations with free charging offerings as of March 2025, split by location type (ZapMap, 2025).

Figure 3-3: Number of charging stations located in the UK which offer free charging, split by location type



Source: (ZapMap, 2025)

While free charging is offered across a large volume of stations across the UK, it is not known what proportion of these examples offer free charging purely as an amenity against those which compensate for operational costs through alternative revenue streams.

Charging providers are also establishing partnerships with other stakeholders in EV charging to offer tariff bundles in which flat rates are offered to users which include prices for charging and other hardware. One example is the partnership between Podpoint and EDF for the UK market, which allows users to purchase AC charging for an initial payment which is £600 less than its actual cost. This cost is then spread across a two-year period in the tariff, priced at £2,139 per year and gives drivers cheaper energy rates for both their vehicle and home. The companies claim this scheme could save drivers between £460-538 per year (Pod Point, 2024) (EDF, 2024). Another example of an energy bundle is the V2G bundle developed by BYD, Octopus and Zaptec which was unveiled at the Energy Tech Summit in June 2025. The bundle is priced at less than £300 per month and includes a leased BYD Dolphin with V2G capability, a bidirectional Zaptec pro charger and access to a smart tariff which offers free overnight charging (Octopus Energy, 2025). The tariff is subject to conditions, such as ensuring vehicles are plugged into the grid 20 times per month for at least 12 hours each time to ensure support to the grid (Electric Drives, 2025).

3.3 CHALLENGES FACED BY CPOS AND EMSPS

Cost of grid reinforcement upgrades

Capacity constraints are the biggest challenge for EV charging network operators in 2025 – a survey conducted with 300 full-time employees working in the EV charging industry revealed this as the top concern, with more than 90% of respondents expecting lack of grid capacity to hinder their growth over the next year (Driivz, 2025). This results in high costs and limited feasibility of expanding Grid Connection Points (GCPs). In many cases, Distribution System Operators (DSOs) either restrict such upgrades or impose significant financial burdens, compelling CPOs to seek alternative solutions to manage energy demand. Complicating matters further is the variation in grid operator billing intervals across European countries. For instance, while Belgian DSOs use 10-minute billing periods, German operators rely on 15-minute intervals. These discrepancies make it increasingly difficult for CPOs operating across borders to harmonise their operations and optimise grid fee management, as they must navigate diverse regulatory frameworks and compliance standards in each jurisdiction. In an effort to circumvent the need for expensive grid reinforcements, some operators have turned to battery energy storage systems. However, the effectiveness of these systems is often undermined by the lack of integration between Energy Management Systems (EMSs), chargers, EVs, and storage units—especially when sourced from different manufacturers. This lack of interoperability can result in suboptimal energy use, elevated operational costs, and ultimately, increased revenue losses (Gridx, 2025).

Bureaucratic processes to facilitate grid upgrades for EV charging infrastructure

Navigating the bureaucratic landscape to secure grid upgrades for EV charging infrastructure remains a significant hurdle for CPOs in Europe. The challenges presented by the bureaucratic process are related to the regulatory and permitting framework, as well as the need for further investment to meet current grid upgrade needs.

Permitting requires a clear, standardised and expedited permitting procedure for EV charging projects. Current problems in relation to permitting procedures, according to a study by the Sustainable Transport Forum (Sustainable Transport Forum, 2023), include lengthy processes, such as:

- Lengthy administrative processes involving different permits and granting authorities that vary across Member States
- Lack of clarity involving the application procedure and/or competent authorities assessing the permit application, for example, varying definitions for what is considered a 'recharging station', sudden changes in responsible permitting body, and unpredictability for response times and final decisions
- Lack of transparency on costs
- Absence of a clear assessment framework and/or evaluation criteria

To facilitate and expedite permitting procedures, the permitting process requires defined timelines that are as short as possible as well as improved clarity and predictability. Local public authorities should also receive improved technical support by Member States as part of the national policy framework to streamline procedures, this could also be supplemented with a prioritisation framework for certain grid connection requests to ensure priority grid upgrades, such as those aligned with climate and social objectives, are prioritised (ChargeUp Europe , 2023).

Financing, due to the high upfront costs of grid upgrades and the uncertain return on investment can also be a barrier to grid upgrades. Upgrading grid infrastructure requires a large upfront investment which can put off investors due to the challenges of demonstrating the long-term economic benefits of these projects to regulators and the long payback periods associated with grid modernisation, particularly for private investors (Sustainability Directory, 2025). Furthermore, the uncertainty surrounding future energy demand and technological advancements can also slow investment. Smaller DSOs may struggle even more to attract this investment. At the EU level, there are a number of financing opportunities available such as through the European Investment Bank (EIB), which provides loans and grants to projects, or through the European Bank for Reconstruction and Development (EBRD), which also provides financing for transmission and distribution projects, among others such as the CEF-E or Modernisation Fund. Private investors also play a role such as OEM joint investments or DSOs. Financing is needed when the utilisation of chargers is not yet high enough for private companies alone to be profitable. The key challenge currently lies in the fact that the investment needed is higher than the current rate at which it is made available. According to the International Energy Agency (IEA), meeting global energy and climate commitments by 2030 will require electricity grids to expand by more than 20% in length with annual investment in grid infrastructure needing to double, from approximately US$300 billion today to around US$600 billion (EPRS, 2025). For Europe, it is estimated that the total annual investment needs up to 2030 are between €65 to €100 billion (Eurelectric, 2024).

Legacy electricity distribution infrastructure as a bottleneck for electrification

Europe's ageing electricity distribution infrastructure presents a major bottleneck for the expansion of EV charging networks. In countries such as the Netherlands, Belgium, Germany, and Italy, the bureaucratic processes required to secure grid extensions are often protracted, taking anywhere from two to five years for approval. Furthermore, Distribution System Operators (DSOs) may deny requests for expanding GCPs altogether, citing system constraints and capacity limitations. These delays and restrictions force CPOs to operate within existing grid limits, which can severely hamper their ability to scale and optimise charging infrastructure. Without implementing solutions such as dynamic load management or smart charging systems, the power that is available is frequently underutilised. This results in inefficiencies, reduced profitability, and increased risk of localised grid overloads or service disruptions (Gridx, 2025).

Uptime and Reliability

Ensuring high uptime and reliability across EV charging infrastructure is critical to supporting the transition to e-mobility, yet it remains a multifaceted challenge for both CPOs and eMSPs. One of the core technical hurdles stems from interoperability issues between OEMs—chargers, batteries, and photovoltaic systems frequently operate using different protocols. This lack of standardisation complicates energy optimization and system integration. A unified interface capable of connecting multiple OEM backends is essential for enabling real-time, automated energy management that reduces grid congestion and maintains stable operations regardless of manufacturer (Gridx, 2025).

Adding to the complexity is the uncertainty around the future mix of charging speeds—whether fast, ultra-fast, or standard—posing strategic challenges for CPOs in terms of hardware selection and site placement. This mix is influenced by various country-specific factors such as urban density, consumer charging habits, and the national ratio of BEVs to plug-in hybrid electric vehicles (PHEVs). In responding to evolving demand, CPOs must ensure that expanding infrastructure does not come at the cost of uptime or compromise other competitive performance criteria (EY, 2023).

Operational reliability is further threatened by issues such as hardware malfunctions and inconsistent definitions of reliability standards. Consumer surveys have indicated that the reliability of charging infrastructure can be improved by accelerating the standardisation of reliability measurements. This would ensure an interoperable e-mobility ecosystem. Reliability issues can occur even if the EV charger is online and connected to the grid. Some issues encountered by users include unresponsible or unavailable screens, payment system failures, or vehicle-to-charger communication failures, network failures and broken connectors. With each CPO potentially employing different metrics and service expectations, even within the same country, this can complicate cross-border charging experiences and add to charging anxiety among potential new EV users (E-Mobility Europe, 2025). Environmental exposure and vandalism also present design and maintenance challenges, necessitating durable, weather-resistant installations at charging sites.

For eMSPs, service quality is heavily dependent on the timely and accurate transmission of data from the charging stations. Robust communication protocols, such as the OCPI, are crucial to ensure seamless connectivity between CPO systems and eMSP platforms (E-Mobility Europe, 2025). Similarly, the use of OCPP facilitates remote diagnostics, over-the-air firmware updates, and real-time maintenance which are all vital for keeping EV Supply Equipment (EVSE) operational and reducing downtime. A survey conducted by Driivz with 300 employees in the EV charging industry identified optimisation of operations, to ensure networks run smoothly, maintain stability and availability while enabling seamless charging experiences, as a key priority in helping operators maintain a reliable service (Driivz, 2025).

Timeliness of data transmission from charging stations to e-MSP platforms

The timeliness of data transmission from charging stations to e-MSP platforms contributes significantly to a seamless user experience. Up to date and consistent data systems contribute to a better user experience for drivers who benefit from real-time information on charging availability, pricing and compatibility with their vehicles. These data contribute to effective route planning and reducing range anxiety. The key interaction between CPOs and eMSPs is the exchange of data on EV charging sessions, location, user identification and payment/billing data. This direct connection is established via Open Clearing House Protocols (OCHP) and Open Intercharge Protocol (OICP) communication protocols that enable information exchange between the two parties, however, each connection between a CPO and an EMSP involves contractual negotiation, specific technical developments and data processing, making it difficult to connect directly to all players (Eurelectric, 2024).

CPOs and e-MSPs face challenges expanding internationally due to the existence of different protocols, regulations and multi-currencies that need to be integrated into the roaming capabilities of their networks. Additionally, new protocols are regularly being developed and various protocols are necessary for the implementation of different charging models (i.e., V1G, G2V and V2G).

Barriers to market entry/exclusionary conduct

Several structural and strategic factors contribute to the existence of market barriers. In many local markets, a single CPO retains significant power due to exclusive concessions or long-term contracts, limiting new entrants and potentially leading to higher prices and reduced consumer choice (European Commission, 2023). Early market entrants may benefit disproportionately from network effects and economies of density, enabling them to consolidate their position. This raises concerns about sustainability of competitive dynamics without proactive regulatory oversight.

Vertical integration between CPOs, eMSPs, energy providers and public authorities also raises competition concerns. While such integration can lead to efficiencies, it risks excluding third-party providers if access to infrastructure or data is restricted. Though current regulations aim to address these risks, vigilance is required to prevent foreclosure practices. Additionally, horizontal cooperation such as joint ventures and bilateral agreements may improve coverage in underserved areas but can also restrict competition if these partnerships are not monitored, as it could result in a reduced incentive for innovation and a loss of market diversity (European Commission, 2023). Exclusionary conduct could also be a key concern as a result of certain partnerships between key actors.

Finally, exclusive contracts with property owners of ‘hot spot’ locations such as shopping malls, highways and other public spaces may foreclose competition from access to high demand sites.

Optimal ratio of Level 1/2/3/4 charging stations

Determining the optimal mix of Level 1, 2, 3, and 4 chargers represents a strategic and operational challenge for CPOs and eMSPs, as it directly impacts infrastructure investment, user experience, and network efficiency. The right amount, types and locations of chargers can encourage a shift from home overnight charging paradigms to daytime public and workplace charging, for example, or encourage more PHEV drivers to use electricity for a greater proportion of their driving (ICCT, 2017). However, determining between installing slower AC charging (level 1 and 2) and faster DC charging (level 3 and 4) must take into account a number of important variables, including location, vehicle battery capabilities, driver behaviour and grid constraints, to ensure a convenient charging network for users.

In urban areas, effective planning of charging infrastructure must take into account factors such as parking restrictions, working patterns, limited grid capacity, and installation costs. In contrast, highway corridors and commercial fleet depots face different demands, including a higher turnover of users and, in some cases, greater grid availability due to their more remote locations. Ensuring sufficient charger coverage in urban and suburban areas remains a key priority to support the daily circulation of electric vehicles. Level 2 chargers are often preferred in these areas because they are less expensive to install, support overnight charging, and are well-suited for locations with longer parking durations. On the other hand, highway corridors and fleet depots increasingly require Level 3 or Level 4 chargers to meet the need for rapid charging and quick vehicle turnaround (Szumska, 2023). While public charging infrastructure is vital for long-distance travel and for drivers without access to home chargers, the vast majority of charging is expected to take place at private locations such as homes or workplaces, making private infrastructure the backbone of the EV ecosystem (T&E, 2022).

However, deploying high-speed chargers poses significant challenges. Level 3 and 4 chargers entail substantially higher capital and operational expenditures compared to Level 1 and 2 alternatives. These chargers require advanced power electronics, liquid cooling systems, and robust safety mechanisms, all of which drive up equipment costs. Additionally, the installation of high-speed units often demands extensive grid reinforcement, particularly in areas not originally designed for such high power loads (Mastoi, M.S., et al., 2022). This can include upgrading local transformers, increasing connection capacity, or even coordinating with grid operators to manage load balancing. These upgrades are not only costly but can also involve lengthy permitting processes and coordination with multiple stakeholders, delaying deployment.

Despite these investments, high-speed chargers frequently experience low utilisation rates in the early phases of network rollout. One of the primary reasons for low utilisation rates is the fact that most of the early adopters in the UK have access to private garage of driveway – 72% of individuals have access to a private charger in urban areas, 72% in town/fringe, and 93% in rural areas, according to a recent survey conducted by the UK government (BEIS, 2022). The same survey revealed that only 8% of EV owners in the UK use public chargers once or more than once a day. This results in low utilisation rates of public chargers, particularly in less busy or rural areas. The low utilisation rates reduce the profitability of public chargers, which contributes to the uncertainty of revenue streams for CPOs.

4. CONSUMER PERSPECTIVES AND NEEDS

4.1 INTRODUCTION

As EV uptake continues, the demand for and roll out of public charging will also increase. Although 83% of chargers were private in 2024 (ChargeUP, 2025), a survey conducted by McKinsey found that only 50% of charging sessions take place in consumers' homes (McKinsey & Company, 2024)[4]. This is followed by the consumer's workplace with 10% of charging sessions occurring at the workplace. However, 42% of respondents who do not own an EV state that they cannot currently charge at home, highlighting the need for investment in public charging points to encourage the uptake of EVs (McKinsey & Company, 2024). It is important that consumer perspectives and needs are identified and any issues addressed so that public charging infrastructure is sufficient for the increased demand and does not hinder further EV uptake. This section focuses on the perspectives and needs of consumers in relation to the use of public electric vehicle charge points by consumers, including in relation to decision criteria for EV charging, experience of payments at charging points, and physical access and use of charging points.

4.2 CONSUMER NEEDS AND DECISION CRITERIA FOR EV CHARGING

There are a range of factors that contribute to consumers' needs and decision-making criteria in relation to their preferences and experiences of EV charging. Research has been undertaken to further understand these needs and decision criteria in relation to the use of public EV charging infrastructure. In a study by the European Alternative Fuels Observatory (EAFO), four key EV charging consumer priorities are identified:

- Convenience (55% of consumers): Find nearest and fastest charger, likely willing to pay for time saved
- Price (25% of consumers): Willing to sacrifice charging time for lower cost
- Loyalty program (10% of consumers): Earn and redeem points on charging with partner retailers
- Quality (10% of consumers): Willing to pay extra or sacrifice time for charging with clean renewable energy (PwC, 2021) (EAFO, 2024).

As the highest priority for consumers, convenience is a highly influential factor for the uptake of EV users. Convenience can encompass a variety of other factors and considerations, which can ultimately influence a consumer to use a particular charging point (or indeed their perception of charging point use and initial EV purchase decision). A further consumer survey of European EV drivers undertaken in 2023 (EAFO, 2024)[5] revealed that the most important characteristics of public recharging sessions are:

- Fully operational recharging station when arriving (66%)
- Clear and transparent price information (59%)
- Short or no wait time to access recharging point (55%)

The evidence and understanding relating to these aspects are explored in more detail in the following sections, including provision and distribution of chargers; charging point speeds and waiting time to charge; reliability of chargers; charging anxiety; price of charging and understanding costs; and charging energy source and its impact on decision making.

Availability and deployment of charging points

Public charging points will be necessary to expand the EV market and to allow a wider range of consumers to access EVs (Social Market Foundation, 2025). The number of public charging points in the EU is expected to increase to 3.8 million over the next decade (ChargeUP, 2025). As identified above and discussed in more detail in Section 6 (Charging infrastructure deployment in the EU), EV charging infrastructure is being rolled out across the EU, but the deployment of charging points will differ by Member State / region / city location (refer to chapter 6).

Currently, the limited rollout of public charging infrastructure is a barrier to the uptake of EVs as the public charging network is often perceived as inconvenient and unreliable. A report by EY states that a lack of

[4] McKinsey survey: Conducted in December 2022 – 30,978 responses from current mobility users in 15 markets, including Australia, Brazil, China, Egypt, France, Germany, Italy, Japan, Norway, Saudi Arabia, South Africa, South Korea, the United Arab Emirates, the United Kingdom, and the United States.

[5] EAFO Consumer Survey: European BEV and non-BEV drivers - 19,080 total responses - BEV (2,046) and non-BEV drivers (17,034)

charging stations was a key reason for reluctance to purchase an EV and it highlights significant variation in the ratio of EVs to public charging points across Europe (Simpson & Sullivan, 2023). Furthermore, a 2024 survey of EV consumers found that 80% of respondents who are considering an EV believe that the current geographic availability of public chargers is insufficient and 15% believe that the future network will not be able to cope with the demand (McKinsey & Company, 2024).

Similarly, consumers are dissatisfied with the current public-charging network (McKinsey & Company, 2024). 28% of UK survey respondents believe that more charging facilities are needed at motorway service areas to improve the public charging network which will help facilitate EV drivers to do long distance trips (Britain thinks, 2022)[6]. The experience and concerns of current EV owners is similar to potential EV buyers as the same survey revealed that 70% of EV users are dissatisfied with the current network of public charging infrastructure and only 10% of EV users are happy with the availability of public chargers (McKinsey & Company, 2024). Similarly, there is a concern that insufficient distribution of charging infrastructure will hold back EV uptake for households who are unable to install private charge points (Social Market Foundation, 2025). The potential lack of public chargers in some locations is concerning as it has been suggested that more than half of EV drivers without off-street parking rely solely on the public charging network in some areas (EVA England, 2024)[7]. For effective deployment of charging points, countries need strong support for EV policies, and a stable, predictable CO_2 target framework is essential (ChargeUP, 2025).

A study by Steer in 2023 (prepared for FIA) found that information regarding opening times is not always readily available and there is very little capability for EV users to book or reserve charge points. Additionally, there are inconsistencies across charging point websites regarding information on how many charging points are available at each location and it can be unclear whether the charging point is a single or twin socket which could cause confusion for consumers (Steer, 2023). More widespread information aimed at the public on the location and availability of charging points would assist in raising awareness amongst EV owners (and potential owners).

Consumers also express frustration with the operational availability of chargers – that is whether a public charger is functioning and free to use when needed. Availability of public charging points (or perceived availability of charging points) is a key concern for current and potential EV users (Visaria, Jensen, Thorhauge, & Mabit, 2022). Both the perceived scarcity of chargers in convenient locations and the difficulty in accessing an available and operation charger are cited as two of the top five disadvantages of electric vehicles, acting as a potential barrier to adoption of EVs (EAFO, 2024).

The CTEK Electric Vehicle 2023 survey[8] asked respondents about their least favourite aspects of owning/driving an EV. Their answers included:

- Difficulty of charging in nearby/public places (6%).
- Not having enough charging locations nearby (6%).

In a survey of European drivers, 56% indicated that they encounter broken public chargers at least one in five times when they arrive at the charging point aiming to charge their vehicles (CTEK, 2023). These issues lead to a perception of unreliability that deters both current users and potential EV users.

Addressing both the deployment of infrastructure and its operational availability will be critical. Policymakers must ensure not only that chargers are present in the right locations, but also that they are functional, accessible and supported by clear, consistent information. Only by tackling both dimensions of availability can public confidence in the public EV charging network be built and sustained.

[6] Britain Thinks Survey: 848 total respondents - UK EV drivers aged 18+ with continuous access to either a BEV or PHEV
[7] EVA England survey: 1,749 EV drivers in England, during August 2024.
[8] CTEK Electric Vehicle survey - 11,176 respondents - BEV and non-BEV drivers in UK, France, Netherlands, Norway and Sweden, 2023

Summary:

- Wide disparities in the geographic deployment of charging points remain across countries limiting access for those without private charging points
- At the same time, many EV users face persistent challenges with operational availability, reinforcing a perception of unreliability that deters both current users and potential buyers
- Public charging infrastructure must be both widely distributed and reliably accessible to support EV adoption. Addressing gaps in charger location, functionality and user information is essential to build consumer confidence and meet growing demand.

Charging point speeds and waiting time to charge

The charging speed of public chargers is also an important convenience factor for consumers. Those EV owners who are charging at their homes or places of work have less time constraints for their charging activity, compared to those using public charging points, who are likely to have a shorter window within which they can charge their vehicle. A 2024 survey of EV users found that 42% of respondents identified speed as the most important factor when choosing a public charging point and 60% of respondents want charging time to be under 30 minutes (McKinsey & Company, 2024). A UK survey by Britain Thinks found that when asked about the top three aspects that could be improved about the public charging network, top responses included more rapid chargers (37%) and quicker charge times overall (24%) (Britain thinks, 2022).

A further consideration relating to charging time is the time spent by the EV owner waiting to use a charging point, as they may already be in use by another EV owner. In a survey of European drivers, their top response regarding their least favourite thing about owning/driving an electric vehicle ‘having to wait while my EV recharges’ (10%), followed by ‘having to queue for an available public charger’ (7%) (CTEK, 2023). In the same survey, 60% of respondents indicated that they have to wait to use a public charger as it was being used by another EV user (one in five times), with 4% experiencing this issue every time, and only 12% state they never have to queue (CTEK, 2023). In another EU survey, 31% of respondents indicated that they never wait when a charging point is occupied (leave without charging), whereas 32% waited for 15 minutes or less before leaving. A further 31% waited between 15 minutes and an hour, whereas only 6% waited more than an hour (EAFO, 2024).

Summary:

- Charging speeds and wait times are major concerns for EV users relying on public infrastructure. Faster chargers and reduced queuing are essential to improve convenience for users and encourage wider EV adoption.

Reliability of chargers

Reliability of chargers for EV users means having sufficient access to a public charging network that consistently works (E-Mobility Europe, 2025). However, across multiple surveys and studies the current public charging network is consistently viewed as unreliable and public charging infrastructure is negatively perceived. In a survey of European drivers, respondents indicated that they sometimes encounter chargers that are not working, with 14% indicating that they experience this issue one third of the time, 11% half of the time and 4% every time (CTEK, 2023). Consumers experience frequent issues such as network failures, broken connectors, unresponsive/unavailable screens, and payment failures (E-Mobility Europe, 2025). A study by the Transportation Research Interdisciplinary Perspectives found that EV consumers care more about these public charging network issues being fixed than the cost of public charging (Ashby, Weir, & Fussey, 2025). Persistent technical failures and inconsistent charger availability continue to erode user confidence and satisfaction. In a UK survey, 41% of respondents stated that the reliability of public charging networks needs to be improved (Britain thinks, 2022). What consumers ultimately want is simple: charging points that are fast, available and work – a level of reliability that is not experienced for everyone using the current public charging network. As users prioritise fast and functional chargers over price, improving the operational reliability of the existing charging network must become a central focus for policymakers, operators and industry stakeholders alike.

Charging anxiety

Concerns regarding the provision, availability, unreliability of EV public charging infrastructure contribute to charging anxiety for consumers and is a key concern for potential EV users (EY, 2023). A survey by EVA England found that EV drivers who rely solely on public charging infrastructure are less confident and experience greater charging anxiety compared to the average EV driver (EVA England, 2024). 80% of home-charging EV users rarely or never experience charging anxiety compared to just 60% of those relying on public chargers (EVA England, 2024). This charging anxiety experienced by potential new EV users can act as a barrier preventing the widespread adoption of EVs in the future (E-Mobility Europe, 2025). There is also concern over a risk of regression with EV drivers switching back to a traditional combustion engine vehicle (Social Market Foundation, 2025). Therefore, to reduce charging anxiety for EV consumers, the scaling of public charging infrastructure needs to be prioritised and is critical for sustainable EV adoption (EY, 2023).

Price of charging and understanding costs

The pricing options available to consumers have been described in detail in Section 3.2. This section considers the consumer understanding and experience with the cost of charging sessions (payment options and issues are considered in Section 4.3).

The low operating costs of an EV are a common incentive and benefit for consumers switching to and owning an EV. It is therefore important to keep the costs of public charging low (Visaria, Jensen, Thorhauge, & Mabit, 2022). The price of public charging is one of the key factors in charging point selection by consumers, along with speed and availability (McKinsey & Company, 2024) (gridX, 2025)[9]. In a gridX survey of 200 EV owners, 56% indicated that they choose fast charging stations based on the price per kWh (gridX, 2025). In a consumer pulse survey, 35% identified charging costs as a key factor in public charging point selection, after charging speed, which was identified as the most important key factor[10] (42% of respondents (McKinsey & Company, 2024). Furthermore, respondents indicated that they were willing to pay more (approximately 10%) for on-highway charging compared to an inner-city, or destination (‘last stop’) charging – indicating that they appreciate the time savings and convenience of fast charging.

Regarding perceptions of costs, a survey revealed that of those respondents that do all of their charging at public charging points, just under half found their running cost to be cheaper than a petrol/diesel car, and 28% stated they were the same (compared to 91% of respondents that do all of their charging at home who found it cheaper). Nearly 15% found running costs to be more expensive. Those that do charge at home are able to take advantage of cheaper nighttime rates, compared to significantly higher costs at public charging points, particularly when using a rapid or ultra-rapid charger. (EVA England, 2024). All drivers considered, location is the key factor when selecting a charging point, although this changes to cost when considering drivers who only charge publicly.

Regarding information on the approximate costs of charging, this is somewhat determined by a vehicle’s onboard charging capability, varying from vehicle to vehicle – therefore CPOs are likely to struggle to provide indicative costs for consumers as it can be difficult to provide an estimate for the charging session (only one CPO did this) (Steer, 2023). Where estimates are provided, it is difficult to ensure a meaningful and accurate indication of the potential charging cost. Furthermore, fines imposed by charging providers to consumers for overstaying at charging stations are often not explicitly mentioned, and, in some cases have amounted to charging sessions costing hundreds of Euros despite a lack of information. Consumer concerns highlight not only a lack of transparency in the penalty mechanism, but they also view the fines as disproportionate which reinforces a need for regulatory intervention (European Parliment, 2025b; Koelewijn, 2025).

A study conducted by Steer for FIA considered the information provided by CPOs to consumers about the charging points (including a review of nine CPOs). In a review of information provided by CPOs (Steer, 2023), varying degrees of information was provided to the consumer on price, approximate cost and payment options. On pricing, seven out of nine provided some degree of information on price – either as a per kWh or time-based metric, with displays also varying, suggesting inconsistency that can be confusing for consumers.

Energy-based charging rates are considered to be the easiest to understand by consumers. Despite ad hoc prices being comparable to eMSP rates on average, drivers have rarely opted for ad hoc payments.

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[9] In a survey of 200 EV users, the three most important factors for fast public charging stations were 1. Charging speed, 2. Convenience, 3. Cost; and for slow public charging stations they were 1. Convenience, 2. Cost, and 3. Charging speed (gridX, 2025)

[10] In a survey of 27,000+ of those who charge in public or who would consider doing so (Brazil, China, France, Germany, Italy, Norway, South Africa, and the United States)

Differences across MSP pricing models e.g. subscription fees or special prices within networks has made it difficult for drivers to compare charging prices. Given the lack of comprehensive ad hoc price information, consumers have only been able to compare MSP tariffs and ad hoc prices to a minimal extent (ZEV Alliance, 2025).

Summary:

- **Price is a key factor** in consumers' choice of public charging points, especially for those who rely exclusively on public charging; however, public charging is often more expensive than home charging, particularly at fast-charging stations
- **Consumer understanding of costs is limited** by inconsistent and unclear pricing information across charging point operators, with few offering reliable cost estimates before charging
- **Penalties to consumers for overstaying at public charging stations are not explicit**, and can result in fines which amount to hundreds of euros
- **High public charging prices reflect low current utilisation** and the significant investment required to expand charging networks, but costs may fall as EV adoption and charger usage increases over time

Charging energy source – decision making

The charging energy source is another factor that can influence consumers on which charging station they use. In a consumer pulse survey, EV drivers and prospective buyers were asked about the source of electricity used for charging, with 55% of respondents indicating that green charging from renewables is important, and a further 25% agreeing that it is 'nice to have' (McKinsey & Company, 2024). 70% of respondents indicated that they would be willing to pay a premium for sustainable charging. However, the average acceptable price premium amongst respondents was 7% (a reduction from 14% in 2021), indicating that consumers expect green charging as standard. Wider research also shows that EV charging stations using renewable energy are more attractive for EV users (Bruckmann & Bernauer, 2023). In an EV driver survey, only 31% of respondents indicated that they were aware of the origin of electricity being used to charge their vehicles (35% were aware, and 24% indicated neutral) (EAFO, 2024), suggesting that whilst it was important to them, relevant information is perhaps not readily available to drivers.

4.3 CONSUMER EXPERIENCE OF PAYMENTS AT CHARGING POINTS

The AFIR requires that ad hoc payments are possible at all public chargers and, from April 2024, the availability of at least one widely used electronic payment instrument. This was in response to ensuring that EV users are able to pay easily and conveniently at all publicly accessible recharging points without the need to enter into a contract with an eMSP (who may be integrated with a CPO – see section 3.2).

Before accessing charge points, consumers may find it difficult to access information on accepted payment types. In a review of information provided by CPOs (Steer, 2023), varying degrees of information was provided to the consumer on payment options, with only two out of the nine CPOs reviewed providing clear information. The review revealed that payment requirements are often difficult to find on websites and are often not incorporated in CPO maps (Steer, 2023).

In practice, a variety of payment options are available to consumers at charge points, including ad hoc payments as per the AFIR requirement. However, despite this requirement coming into force, payment for recharging in Europe is still typically through a CPO digital app or charging card, rather than payment on the spot (credit/debit card or cash). A survey of consumers suggested that over 60% of payments at both public slow and fast recharging stations are made by charging card or app (EAFO, 2024), whereas a survey of CPOs indicated over 70% (with one third being over 90%) (ChargeUP, 2025)[11].

In another European survey, drivers were asked about their preferred method of payment for EV charging (CTEK, 2023). Responses varied, with 18% citing their preference for one app for all charging points, and a

[11] In a survey of 11 CPOs, 10 indicated that over 70% of payments were via MSP contracts, with 4 of those being over 90% (ChargeUP, 2025)

further 18% citing via credit/debit card. However, other responses included plug and charge automatically (17%), an online app (14%), an app via a QR code (8%), via SMS (6%), or traditional parking meter (6%).

For electric vehicle drivers, the ability to charge on the go is becoming increasingly seamless thanks to roaming, which allows them to start a charging session using either a charge card or a mobile app. Yet, despite the convenience of digital solutions, around 80% of drivers still rely on their RFID cards, highlighting that, for many, physical cards offer quicker, more reliable access, especially when connectivity is patchy or apps lag (ChargeUp Europe , 2023). When it comes to paying for charging, drivers have flexibility: they can choose to pay per session or consolidate costs through monthly billing. This helps individual drivers better manage occasional use, while also giving business drivers, and the companies supporting them, streamlined invoicing and oversight. These evolving payment models reflect a broader reality: driver preferences vary. While many individual users are comfortable tapping a credit card at the charger, professional drivers or fleet users often operate under policies requiring invoicing. As charging infrastructure grows, ensuring that systems adapt to these real-world driver needs is key to smoother adoption and fewer frustrations on the road (ChargeUp Europe , 2023).

Also, although a proportion of payments are made through digital apps, evidence suggests that some consumers are still not taking advantage of subscriptions or tariffs with discounted charging rates (as revealed in a survey of 200 EV owners, where 45% of respondents stated that they did not (gridX, 2025) - suggesting that further education or awareness raising may be needed to ensure that consumers are aware of the benefits.

EV users continue to experience a range of issues when paying for EV charging. A survey of 200 EV drivers, which considered the issues that they face when booking and paying for charging, revealed that multiple payment options are used by drivers (typically three or four, including contactless and different apps), with only 13% having a single payment options that they use all of the time (Paythru, 2024). A survey of European drivers revealed that drivers often had multiple EV charging apps on their phone/other device, with 33% having just 1 or 2, 21% with 3 or 4, and 20% with 5 or more apps (CTEK, 2023).

Issues experienced when making payments at charging points have included having to download a new app at least once in order to pay (87% of respondents), payment problems due to connectivity (80%) and having their card rejected (56%). 61% of respondents indicated that they have left the charging point as payment options were unacceptable (Paythru, 2024).

When travelling abroad, payment issues tend to be less of a concern for EV drivers. Respondents to a survey disagreed that they find it ‘complicated or prohibitively expensive to pay for their recharging abroad (roaming issue)’ (EAFO, 2024). In general, 60% considered their recharging experience abroad to be (very) easy, compared to 10% who through it was (very) hard.

Summary:

- **Ease of payment remains inconsistent** despite new AFIR requirements; many consumers still face unclear or limited information on accepted payment methods, leading to frustration and abandoned charging attempts
- **Most EV drivers rely on multiple apps or RFID cards** rather than using simple ad hoc methods like contactless payment, which remains underused despite being mandated, suggesting that implementation lags behind regulation
- **Payment-related issues are common** (e.g., app downloads, connectivity problems, rejected cards), indicating a need for more streamlined, user-friendly, and transparent payment solutions to improve consumer confidence and satisfaction.

4.4 PHYSICAL ACCESS AND USE OF CHARGING POINTS

The AFIR aims to address issues relating to access and use of publicly accessible recharging stations to ensure that they are user friendly and non-discriminatory, including for older persons, persons with reduced mobility and persons with disabilities. In their National Policy Frameworks (NPF), Member States are required to identify those measures that ensure publicly accessible recharging and refuelling points are accessible to these groups in accordance with the accessibility requirements of Directive (EU) 2019/882 (by 31 December

2024). The AFIR also refers to technical specifications for recharging stations to ensure access for users with disabilities.

The AFIR suggests that the safety and security of users of recharging stations could be addressed by equipping the recharging stations with emergency buttons, displaying emergency services contact information, ensuring adequate lighting or by any other appropriate measures.

A range of research, including consumer surveys, has been undertaken to further understand the issues encountered by potential EV users when attempting to access and use charging points, including in relation to disabled users, the elderly and other groups such as women.

Charging infrastructure and the surrounding built environment does not consistently meet the needs of **disabled users**. A number of surveys and studies have been undertaken to understand the issues that users are facing (tend to be from the UK, with little evidence available from the rest of Europe). In the UK annual 'Access survey' (6,000 respondents) it was reported that 75% of disabled people with experience of public electric charging points stated that accessibility is either very bad or bad (Euan's Guide, 2024)[12]. Additionally, 38% stated that they would not consider having an electric vehicle, with explanations including a lack of belief that the infrastructure is viable, and that many public charging points are inaccessible. Access survey respondents that had experience of public electric vehicle charging points were asked if they had experience of a range of issues at a charging point, with over a third of respondents stating that they did (see Table 4-1).

A study by the Energy Saving Trust (UK) considered the uptake of EVs for disabled consumers, examining the potential barriers to electric vehicle and infrastructure (charging point) use (Energy Saving Trust, 2022)[13]. In particular, accessibility issues relating to disabled users and charging points were identified by stakeholders. In a review of available evidence, it was concluded that the key issues facing disabled users related to the built environment and the charging point itself, further identified in Table 4-1 below. Finally, in a wider survey focusing on charging for EV drivers more generally (1,749 respondents), 13% of respondents identified as disabled (EVA England, 2024). Again, disabled users cited a range of issues that they encountered when attempting to access and use charge points as a disabled user that were consistent with other studies (see Table 4-1).

Table 4-1: Most common accessibility concerns for disabled consumers around EV charging points and their built environments

Experience of the following issues as a disabled user (% of respondents) (Euan's Guide, 2024)	Most common accessibility concerns around charging points and the built environment (Energy Saving Trust, 2022)	Issues encountered as a disabled user (EVA England, 2024)
• Size and layout of the bay not suitable for my access requirements (37%) • Screen too high or too difficult to read (42%) • Payment or card mechanism too high or too difficult to use (42%) • Fixed charging cables too heavy, not long enough or otherwise unsuitable (49%) • Charger inaccessible due to being on a raised plinth or pavement (48%)	Charging points: • Connectors being too high • Connectors too awkward to plug in • Stiff cables • Dirty cables • Poor user interfaces • Heavy cables • Poor night time useability Built environment: • Lack of dropped kerbs • Crash bollard interference • Incorrect disabled bay markings/signage	• Charger inaccessible due to being on a raised plinth or pavement (33%) • Charging cables are too heavy (30%) • Size and layout of the bay are not suitable for access requirements (25%), • Surrounding pavements and environment lacking dropped kerbs (15%) • Screen too high (6%)

[12] Euan's Guide survey – Over 6,500 disabled respondents in the UK, 2024.

[13] Energy Saving Trust – Based on literature review/research but also workshops with automotive industry stakeholders (x11), chargepoint operators (x7) and disabled consumers (x 8)

Experience of the following issues as a disabled user (% of respondents) (Euan's Guide, 2024)	Most common accessibility concerns around charging points and the built environment (Energy Saving Trust, 2022)	Issues encountered as a disabled user (EVA England, 2024)
• Surrounding pavements and environment lacking dropped kerbs (62%) • Size and layout of the bay not suitable for Wheelchair Accessible Vehicles (WAVs) (42%)	• Poor chargepoint/cable placement • Lack of shelter from weather • Inadequate lighting • Inconvenient location	

The AFIR identifies many of these examples, i.e. "providing sufficient space around the parking place, ensuring that the recharging station is not installed on a kerbed surface, ensuring that the buttons or screen of the recharging station are at an appropriate height, the weight of the recharging and refuelling cables is such that persons with limited strength can handle them with ease, and the user interface of the related recharging stations should be accessible". In the case of these examples, the accessibility requirements set out in Directive (EU) 2019/882 should therefore be met. However, based on the survey/evidence undertaken in the last couple of years, responses suggest that disabled users are still experiencing charge point accessibility issues.

Although the use of EVs and EV maintenance may be easier for older people, charging may continue to present some concern, in particular lifting heavy charging cables, bending, and standing for extended periods of time (although similar concerns for ICEs). To overcome some of these issues, approaches could include wireless or automated charging systems, ensuring charging stations consider accessibility features (including wheelchair ramps), and provision of nearby convenience stores where users can sit and rest while refuelling (William Joseph, 2023).

In terms of gender and EV charging, women tend to have more concerns regarding personal safety compared to men when using public charging stations. In one survey, 55% of the women surveyed, versus 70% of the men surveyed, indicated that they felt 'very safe' (ZEV Alliance, 2024). Some of the reasons for feeling less safe included the location of charging points in isolated or dark areas, insufficient lighting when having to charge at night, concerns about leaving the cable exposed while charging, and concerns about potential theft of the vehicle. Another survey cited in the same source found that only 43% of women felt safe using public chargers, compared with 53% of men, reinforcing the view that there is a disparity between genders.

Women tend to have other concerns relating to charging, including being more worried about not being able to recharge when needed (49% of women versus 39% of men), and being more worried about charging times compared to men (43% of women, vs 35% of men (ZEV Alliance, 2024).

Summary:

- **Accessibility remains a significant barrier** for disabled users, older individuals, and others with specific needs, with widespread issues around charge point design, cable handling, screen height, and the surrounding built environment.
- **AFIR mandates accessible charging**, but recent surveys indicate that many users, especially disabled people, continue to face exclusion due to poor infrastructure design and a lack of compliance with EU accessibility standards.
- **Safety and usability concerns persist**, particularly among disabled users, women and the elderly, highlighting the need for improved lighting, secure locations, and accessible infrastructure to make charging inclusive and equitable for all.

4.5 SUMMARY OF FINDINGS FOR CONSUMERS

To conclude, understanding consumer preferences and decision-making criteria around public EV charging is critical for accelerating EV adoption and ensuring user satisfaction. EV consumers have diverse needs and decision criteria when it comes to using public charging infrastructure, but convenience and reliability consistently emerge as top priorities. However, findings from the surveys highlight widespread frustration over unreliable charging points, long wait times, insufficient availability, and inconsistent or unclear pricing information. Consumers frequently encounter broken chargers, inadequate location coverage, and charging anxiety, particularly those without access to home charging. These issues not only impact current user satisfaction but also deter potential EV buyers, especially those from households that depend solely on public charging. Affordability and clarity on charging costs further influence where and how users charge, with users often struggling to compare tariffs due to inconsistent or incomplete information. Therefore, as the market shifts towards mass adoption of EVs, there’s an urgent need for better infrastructure reliability, clearer communication from charging point operators, and targeted investments to ensure that consumer needs are met.

Although the AFIR mandates ad hoc payment and inclusion of widely used electronic payment methods at all public EV charging points, real-world implementation remains inconsistent and often confusing for users. Many charging point operators (CPOs) still fail to provide clear or accessible information about accepted payment methods, leaving consumers uncertain before arriving at a charging site. A fragmented payment landscape – requiring users to juggle multiple apps, QR codes, or systems – creates frustration for consumers. While cross-border charging appears to be less problematic, domestic payment challenges persist, indicating a pressing need for better enforcement of AFIR provisions and improved consumer education. Without addressing these payment barriers, the convenience and user-friendliness essential to EV adoption may be undermined.

Despite clear objectives in the AFIR and supporting directives to ensure equal access to EV charge points, recent evidence (particularly from the UK) indicates that accessibility remains a significant barrier for disabled users, older individuals and women. Key concerns for use of public charging infrastructure include poorly designed infrastructure (e.g. raised kerbs, heavy cables, inadequate lighting), inaccessible interfaces, and safety concerns (particularly at night or in isolated locations). Survey data highlights that a majority of disabled users find public charge points inaccessible, leading some to reject EV adoption entirely. Older users face physical challenges with equipment handling, while women express disproportionate concern over personal safety and charging reliability. These findings underscore a critical implementation gap: while the regulatory framework exists, the reality of public charging points fails to meet accessibility standards. Without meaningful action to align infrastructure with users’ diverse needs, the transition to electric vehicles risks excluding these groups and preventing them from using EVs.

5. EUROPEAN ELECTRIC VEHICLE MARKET OUTLOOK

5.1 INTRODUCTION

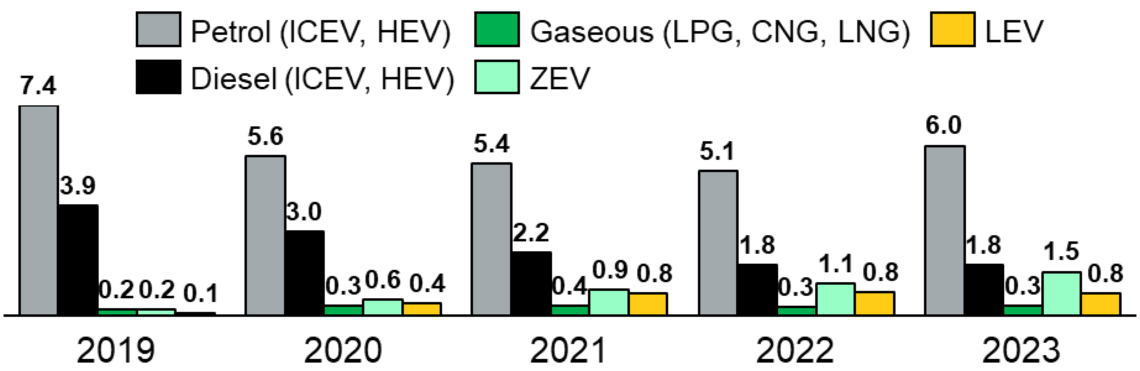
The European Electric Vehicle (EV) market is undergoing rapid transformation, driven by regulatory mandates, declining technology costs, evolving consumer preferences and OEM electrification strategies. Market dynamics vary across Member States (MS), shaped by differences in policy incentives, infrastructure readiness and vehicle availability. Unlike the legacy automotive market – long dominated by Internal Combustion Engine (ICE) technologies – the EV segment is characterised by accelerating innovation cycles, divergent technology pathways and evolving definitions of mobility value. Despite this, convergence around common performance benchmarks including range and cost parity are emerging as a defining trend, reinforcing the transition toward and integrated, low-emission transport ecosystem across the EU.

5.2 EU EV STATUS

New registration data (2019 – 2024)

Between 2019 and 2023, annual registrations of zero emission cars - including BEVs and Fuel Cell Electric Vehicles (FCEVs) - increased consistently, with 2023 volumes (~1.5 million units) nearly three times higher than in 2020 (Figure 5-1). Low-Emission Vehicle (LEV) registrations also rose from 2020 to 2022, followed by a marginal decline in 2023. Throughout the period, LEV registrations remained below zero-emission car volumes, consistently under one million.

Figure 5-1: New car registrations in EU Member States, Norway and Iceland from 2019 to 2023



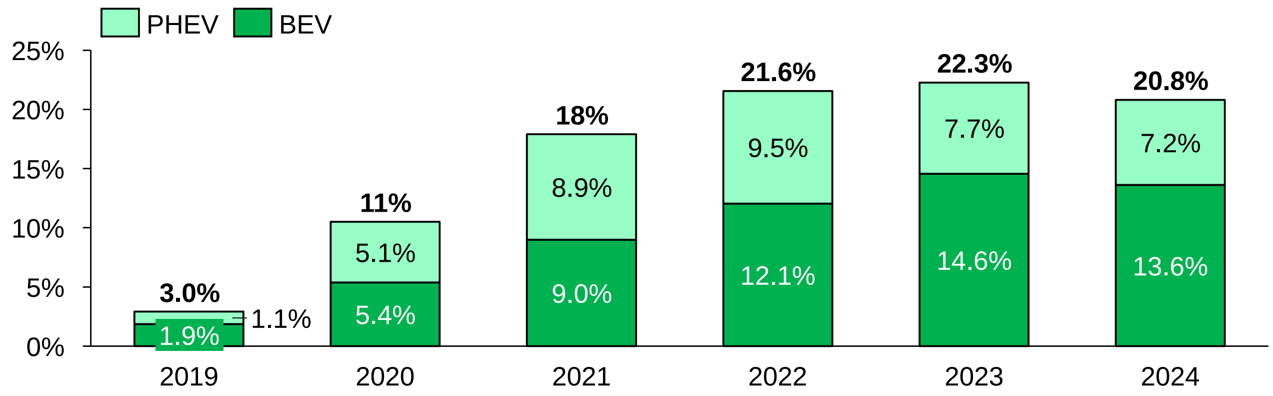
Source: (European Environment Agency (EEA), 2025), Ricardo analyses. Notes: ZEV = BEV+FCEV; LEV = PHEV <50 g/km CO_2.

The EU has witnessed a significant acceleration in the electrification of its light-duty vehicle fleet since 2023, as evidenced by the rise in the combined market share of zero- and low-emission vehicles in new passenger car registrations - from just 3% in 2019 (1.9% BEVs, 1.1% PHEVs) to 22.3% by 2023 (14.6% BEVs, 7.7% PHEVs) (Figure 5-2). This upward trend reflects substantial policy support, growing consumer acceptance, improved model availability, and expansion of supporting infrastructure.

However, the marginal contraction observed in 2024, with zero- and low-emission vehicles falling to a combined share of 20.8% (13.6% BEVs, 7.2% PHEVs), indicates an early inflection point in the rate of progress. This moderation may signal emerging structural barriers: weakening policy incentives in some Member States, lagging infrastructure in key markets, or a slowdown in early adopter demand. It also suggests that while the EU has achieved strong early-stage momentum, the transition from early to mass-market adoption is encountering friction.

The data underscores that fleet electrification is advancing, but sustained acceleration will require targeted interventions, particularly in affordability, charging access, and total cost of ownership parity to avoid stagnation in market penetration during the critical 2025–2030 ramp-up period.

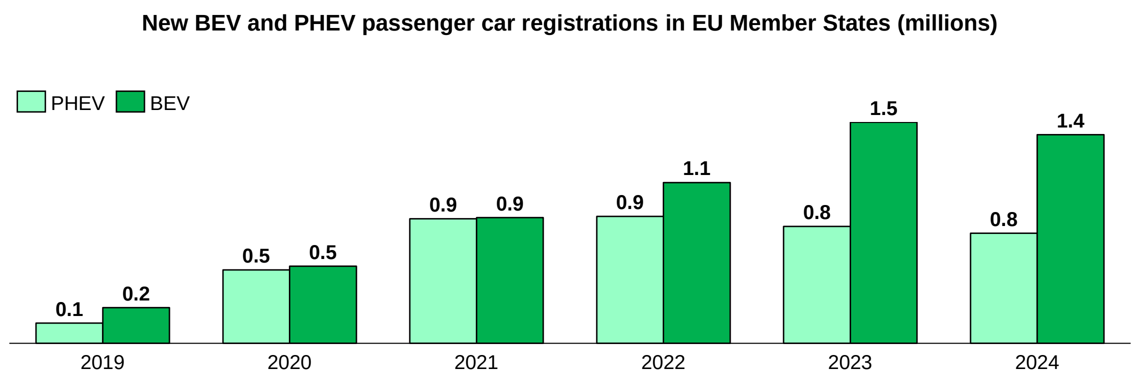
Figure 5-2: Market share of new registrations for zero- and low-emission cars (BEV and PHEV) in EU Member States, from 2019 to 2024



Source: EAFO, Ricardo analyses

From 2019 to 2023, annual registrations of BEV passenger cars increased consistently across EU Member States, with 2023 volumes of new BEV registrations (~1.5 million) experiencing more than a six-fold increase from 2019 (Figure 5-3). Plug-in Hybrid Electric Vehicle (PHEV) registrations also rose from 2019 to 2022, reaching a peak of approximately 880k new vehicles, followed by successive declines in 2023 and 2024, reflecting the contraction in PHEV market share observed in Figure 5-2.

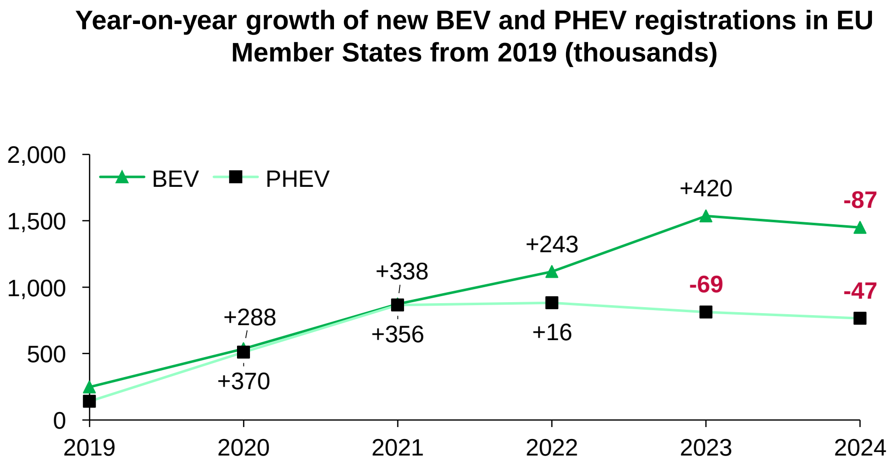
Figure 5-3: Zero- and low-emission new passenger car registrations in EU Member States from 2019 to 2024



Source: EAFO, Ricardo analyses

Zero- and low-emission passenger car registrations have increased steadily since 2019 (Figure 5-4). BEVs experienced the most significant year-on-year growth in new registrations between 2022 and 2023, with an increase of approximately 420k units, representing the highest annual total within the observed period at approximately 1.5 million total vehicles. PHEV registrations rose steadily from 2019 to 2021, before plateauing in 2022 and declining slightly from 2023-24. The most substantial growth in PHEV registrations occurred between 2019 and 2020, with an increase of over 370k units.

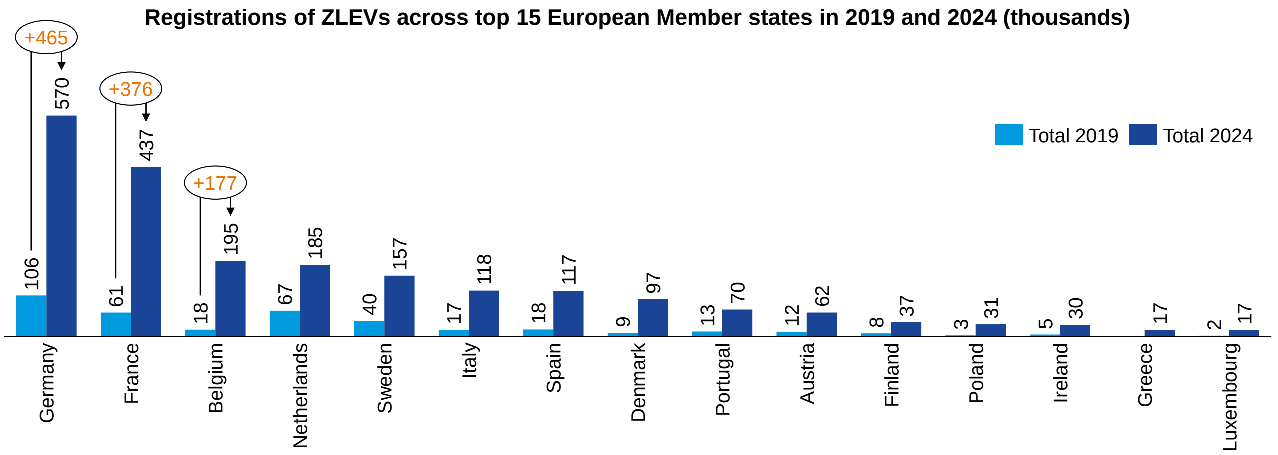
Figure 5-4: Year-on-year growth rate in new registrations of BEV and PHEV passenger cars in EU Member States, from 2019-2024



Source: EAFO, Ricardo analyses

Zero- and Low-Emission Vehicle (ZLEV) passenger car registrations increased in all 27 EU Member States from 2019 to 2024 (Figure 5-5), with many nations seeing a significant growth in uptake rates. In absolute terms, the most significant growth in new registrations was observed in Germany (+465k new registrations), France (+376k), Belgium (+177k) and the Netherlands (+118k).

Figure 5-5: Zero- and low-emission passenger car new registrations in each EU27 Member State, from 2019 to 2024



Source: EAFO, Ricardo analyses

The market share of zero-emission cars among new registrations increased in all 27 EU Member States between 2019 and 2024 (EAFO, 2025),[14] with the most significant growth occurring in the following nations:

- Denmark, with an increase in BEV market share from 2% to 52% (50 percentage point increase)
- Sweden, from 4% to 35% (31% increase)
- Finland, from 2% to 30% (28% increase)
- Belgium, from 2% to 29% (27% increase)

[14] EU27 Member State ZLEV passenger car market share data was extracted from the EAFO website (individual datasets selected from each individual Member State's '*Vehicles and Fleet*' breakdown webpage.

Market shares of low-emission (PHEV) passenger car registrations experienced the highest growth in these Member States:

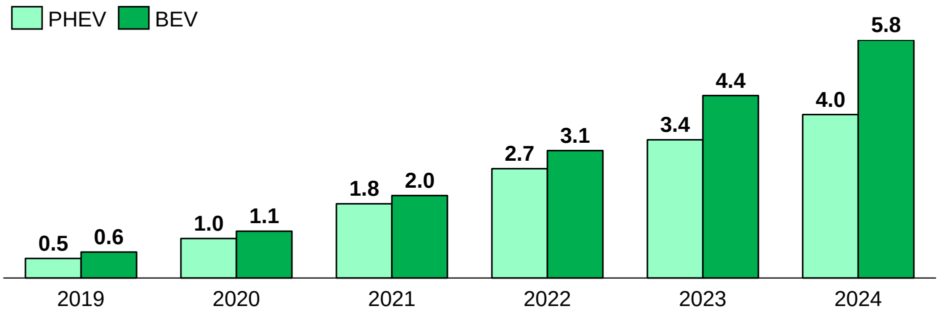
- Sweden, with an increase in PHEV market share from 7% to 23% (near 17 percentage point increase)
- Finland, from 5% to 20% (15% increase)
- Belgium, from 2% to 15% (13% increase)
- Netherlands, from 1% to 14% (13% increase)

Vehicle stock data

EU-wide deployment of zero-emission passenger cars rose significantly between 2019 and 2024, achieving more than a nine-fold increase from ~630,000 to approximately 5.8 million BEVs across the EU27 Member States (Figure 5-6). This growth reflects a Compound Annual Growth Rate (CAGR) of approximately 57%, indicating strong initial momentum driven by regulatory targets (e.g. CO_2 performance standards), OEM electrification strategies and national-level incentives.

The total size of the low-emission vehicle fleet grew by an eight-fold margin over the same period, rising from ~475,000 to nearly 4 million PHEVs. This parallel growth indicates that PHEVs have maintained a stable foothold in the transition, particularly in markets with limited charging infrastructure or consumer hesitancy toward full electrification.

Figure 5-6: EU-wide deployment of zero- and low-emission (BEV & PHEV) passenger cars from 2019-2024 (millions)

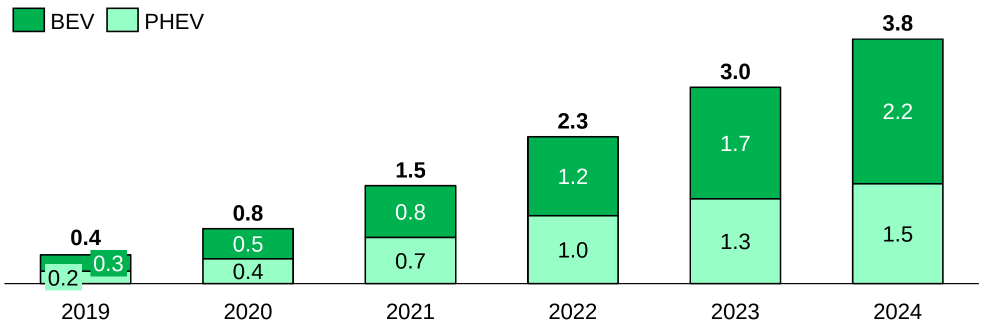


Source: EAFO, Ricardo analyses

Despite the headline growth, this rapid early-stage expansion must be contextualised against the overall EU passenger car vehicle stock, which exceeds 250 million units (Eurostat, 2025).[15] As of 2024, zero- and low-emission vehicles still represent only a marginal share - roughly 4% - of the total fleet (Figure 5-7). This highlights a critical decoupling between new registration shares and cumulative fleet transformation, which inherently lags due to vehicle turnover cycles.

[15] As of 2023, the total EU passenger car fleet exceeded 256 million vehicle units.

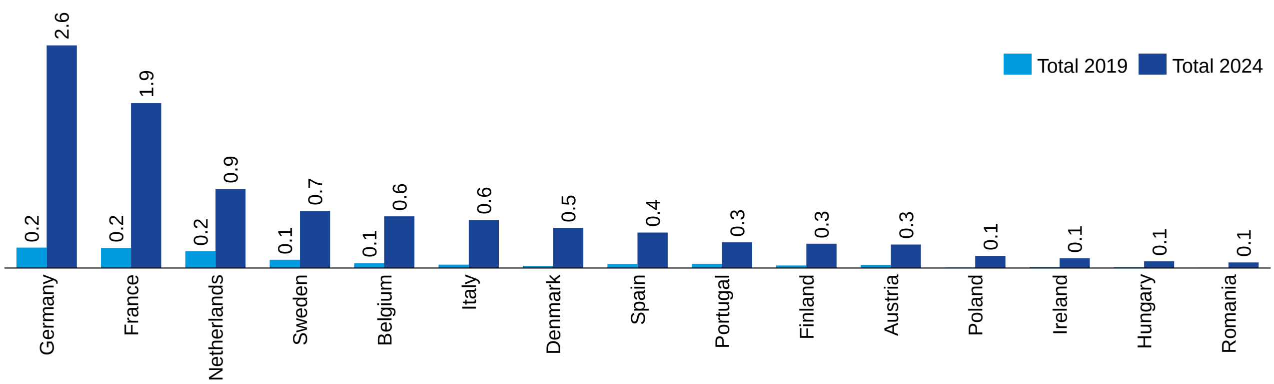
Figure 5-7: Market share of BEV and PHEV passenger cars for EU-wide fleet, 2019-2024 (%)



Source: EAFO, Ricardo analyses

Zero- and low-emission (ZLEV) passenger car total fleet sizes increased in all 27 EU Member States from 2019 to 2024 (Figure 5-8), with most nations witnessing a significant growth in uptake rates. In absolute terms, the most significant growth in total ZLEV fleet size was seen in Germany (+2.4 million new ZLEVs), France (+1.7 million), the Netherlands (+0.7 million) and Sweden (+0.6 million).

Figure 5-8: Growth in zero- and low-emission passenger cars across 15 Member States with the highest volumes, from 2019 to 2024 (millions)



Source: EAFO, Ricardo analyses

The market share of zero-emission (BEV) cars of the total passenger car fleet increased in all 27 EU Member States between 2019 and 2024 (EAFO, 2025),[16] with the largest growth occurring in:

- Denmark, with an increase in BEV market share from 0.6% to 12% (11 percentage point increase)
- Luxembourg, from 0.6% to 7% (near 7% increase)
- Sweden, from 0.6% to 7% (near 7% increase)
- Netherlands, from 1% to 6% (5% increase)

The fleet-wide market share of low-emission (PHEV) passenger cars experienced the highest growth in these Member States:

- Sweden, with an increase in PHEV market share from 1% to 6% (5 percentage point increase)
- Belgium, from 0.7% to 5% (near 5% increase)
- Denmark, from 0.4% to 4% (4% increase)
- Finland, from 0.7% to 4% (near 4% increase)

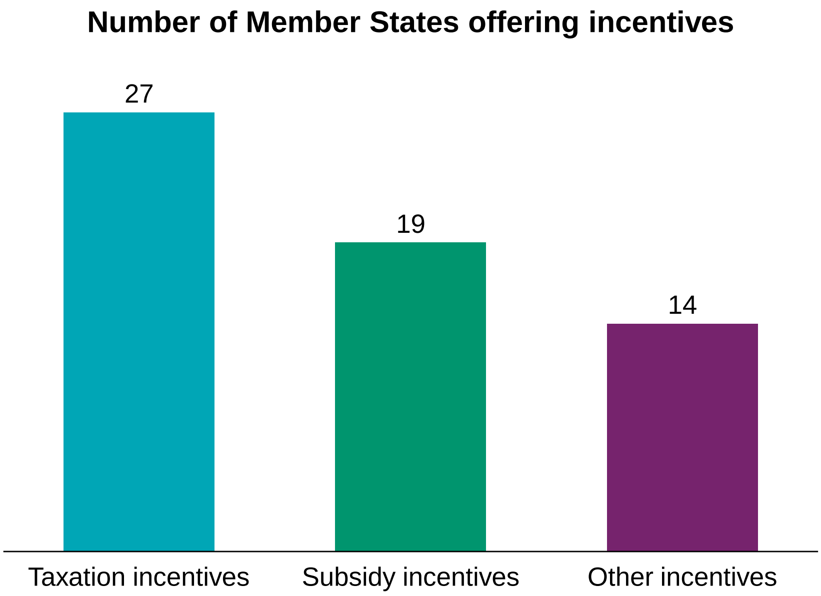
[16] EU27 Member State ZLEV passenger car market share data was extracted from the EAFO website (individual datasets selected from each individual Member State's '*Vehicles and Fleet*' breakdown webpage.

5.3 INCENTIVES

EU Member States use a mix of taxation measures, subsidies, and other financial incentives to reduce the cost of EV ownership and support the transition to zero-emission transport. These tools aim to lower both upfront and operational costs, encourage private and corporate adoption, and promote supporting infrastructure.

The overall landscape for EV incentives is quickly evolving. Since 2021, tax benefits have been broadly offered across Member States, increasing from 26[17] to all 27 Member States by 2025 (ACEA, 2021) (ACEA, 2025). In contrast, the number of Member States offering purchase subsidies has grown more gradually, rising from 17 in 2021 to 19 by 2025. While the strong incentive landscape aids consumers in overcoming the high capital barriers to making environmentally conscious purchase decisions, the early removal of the subsidies may hinder the market and create scepticism among potential buyers. Examples of such may also, in part, be responsible for the reduction in the share of newly registered zero and low emission vehicles in key European markets given the similarity in their timings (MIT Technology Review, 2024).

Figure 5-9: Electric vehicle incentives offered across 27 EU Member states, 2025



Source: (ACEA, 2025). Notes: Member States offering taxation incentives: all – Member States offering subsidy incentives: AT, BE, CY, CZ, EE, ES, FR, GR, HR, HU, IE, LT, LU, MT, NL, PL, PT, SE, SI – Member States offering other incentives: AT, BE, CZ, ES, FR, GR, HR, HU, IE, LT, LU, NL, PL, SE.

Figure 5-9 illustrates the number of EU Member States offering various types of incentives to support electric vehicle adoption, as of 2025. All 27 Member States provide taxation incentives, while 19 (70%) offer subsidy incentives, and 14 (52%) implement other financial incentives, such as infrastructure and mobility benefits. This highlights the widespread use of fiscal tools across the EU, with taxation measures being the most universally adopted.

Taxation incentives

Several European countries have implemented taxation measures to reduce the upfront cost of purchasing EVs. One common approach is the use of emission-based licensing or registration taxes, where the tax amount is directly linked to the vehicle's CO_2 emissions. For instance, Austria's NoVA tax is calculated based on emissions, with a maximum rate of 80%, and includes an additional malus of €80 per gram for emissions exceeding 155 g/km. Another widely used instrument is the reduction or exemption of VAT for ZEVs. In Denmark, VAT deductions are calculated based on battery size, cost, and emissions, while Norway exempts BEVs from VAT up to a price cap of NOK 500,000, taxing only the amount above this threshold. Additionally, tax advantages for companies investing in sustainable technologies are offered to encourage corporate

[17] Estonia was the sole EU Member State that did not provide a tax benefit for electric vehicles in 2021.

adoption of EVs. Hungary, for example, provides an Energy Efficiency Tax Credit that allows companies to deduct up to 70% of their corporate tax liability for qualifying investments, capped at €15 million. For private households, tax incentives for sustainable investments are also available. In Sweden, tax reductions are provided for the installation of solar panels (20%) and home EV charging stations (50%), supporting the broader infrastructure needed for EV adoption.

To reduce the ongoing costs associated with vehicle ownership, several countries apply emission-based annual vehicle taxes. These taxes are typically lower for EVs or waived entirely. In Denmark, vehicles registered after 2021 are taxed based on CO_2 emissions, while Sweden imposes a base tax plus an additional charge for emissions exceeding 111 g/km (ACEA, 2025). Austria offers lower annual vehicle tax for BEVs depending on the capacity and weight, which otherwise ranges from €70 to €2,000. Another key measure is the tax deductibility of company vehicles, which is increasingly tied to environmental performance. In Belgium, the deductibility of company cars is based on fuel type and CO_2 emissions. A phased reduction applies to newly registered ICEVs between 2023 and 2025, with full deductibility eliminated by 2028. From 2026 onward, new ICEVs will no longer be eligible for any tax deduction, thereby incentivizing the transition to EV fleets.

Taxation policies also target the operational phase of vehicle use, aiming to make EVs more cost-effective over time. One such measure is the implementation of fuel and carbon taxes, which increase the cost of operating ICEVs. Ireland includes a national carbon charge within its mineral oil tax, set to reach €63.5 per tonne of CO_2 by 2025 (ACEA, 2025). Austria has introduced a progressive carbon tax, rising from €30 per tonne in 2022 to €55 per tonne by 2025. To support the use of electricity as a cleaner alternative, tax reductions on electricity used for charging are offered. Denmark provides a refund of 94.63 DKK per kWh for electricity purchased at charging stations and exempts employer-paid electricity used for charging employees' private ZEVs from taxation. Finally, reduced taxation for private use of company EVs is another operational incentive. In Germany, employees benefit from a 75% reduction in the tax rate applied to private use of company-owned ZEVs. Austria exempts both the vehicle and the electricity used for charging from taxation as a benefit in kind, further enhancing the appeal of EVs for corporate fleets.

Subsidy incentives

European countries offer a variety of subsidy instruments to reduce the financial barriers to adopting EVs. One of the most prominent measures is the direct subsidy for the purchase or lease of ZEVs, available to both companies and private households. These subsidies typically take the form of a bonus or partial reimbursement of the vehicle's purchase price and may be subject to conditions such as vehicle type, battery size, or price cap. For example, Hungary provides subsidies for companies purchasing electric cars and vans, while the Netherlands offers up to €5,000 for new ZEVs acquired by entrepreneurs and non-profit organisations (ACEA, 2025). Private households benefit from similar schemes: Denmark grants subsidies of approximately €6,500 for vehicles priced below a certain threshold, and France enables low-income households to lease an electric car for €100 per month, provided they meet criteria such as income level, commuting distance, and annual mileage. Other countries, including Estonia, Poland, and the Netherlands, offer subsidies that may apply to both new and used vehicles and are sometimes linked to scrappage programs or social conditions like family size and income.

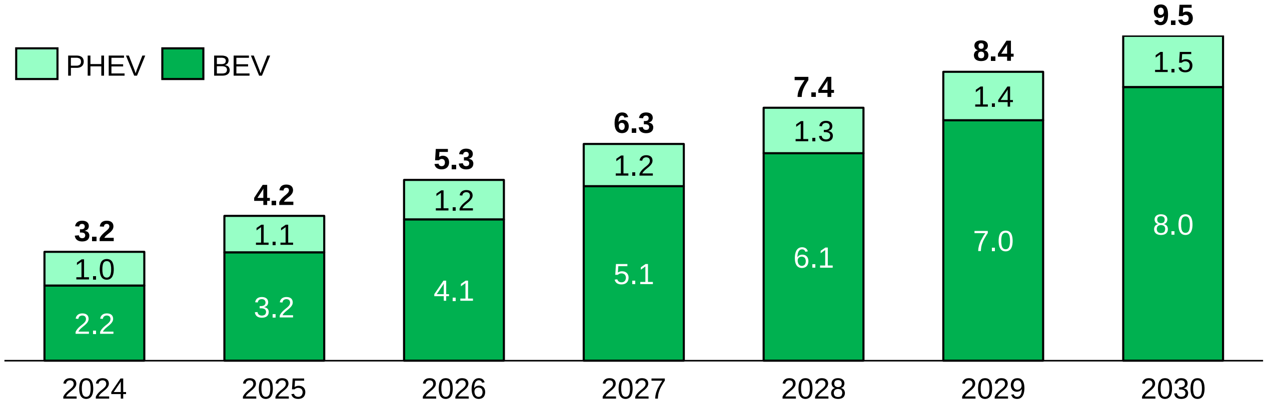
In addition to purchase subsidies, some countries provide operational subsidies to reduce the ongoing costs of using EVs. Denmark, for instance, offers a small refund per kilowatt-hour for charging BEVs and PHEVs, helping to lower electricity costs and improve the cost-efficiency of EV ownership (ACEA, 2025). Furthermore, financial incentives are available to employees as part of broader efforts to decarbonise corporate fleets. In Belgium, the Federal Mobility Budget allows employees to exchange their company car or car entitlement for a tax-free budget that can be spent on alternative and sustainable mobility options, including ZEVs.

5.4 EU EV FORECAST

The Stated Policies Scenario (STEPS), developed by the IEA, provides a data-driven projection of how the European EV market is expected to evolve based on currently implemented and firmly planned government policies (IEA, 2025). Rather than speculating on future pledges or long-term climate ambitions, STEPS reflects the trajectory of EV adoption under the assumption that no additional policies are introduced beyond those already in motion. This makes it a valuable benchmark for understanding what the EV market could realistically look like by 2030 if governments follow through only on their existing commitments.

To construct the STEPS scenario for the EV sector, the IEA collects and analyses a wide range of national and regional policies that directly impact electric mobility. This includes legally binding regulations such as ICE phase-out mandates, vehicle emission standards, and EV sales quotas. It also incorporates financial incentives like purchase subsidies, tax breaks, and investments in charging infrastructure (provided these measures are backed by legislation or detailed implementation plans). Policies that are aspirational but lack enforcement mechanisms or funding are excluded from STEPS and reserved for more ambitious scenarios like the Announced Pledges Scenario (APS).

Figure 5-10: IEA Projected sales of electric passenger cars in Europe, 2024-2030 (millions)



Source: (IEA, 2025), Ricardo analyses. Notes: IEA only provides a European sale total in 2024 and projected a European sale total in 2030 (no projections for EU Member States) – annual sale projections from 2025-2029 have been made using linear progression between 2025 and 2030.

Figure 5-10 illustrates the annual projections of electric passenger car sales in Europe between 2024-2030 using the European STEPS projection for 2030. Between 2024 and 2030, sales in Europe are projected to grow significantly, rising from approximately 3.2 million to 9.5 million annually. This represents a near tripling of total EV sales over the period, however, actual sales may be lower given the higher forecast shown above compared to actual EAFO data in section 5.2. The growth is driven primarily by BEVs, which are expected to dominate the market. BEVs account for roughly 69% of EV sales in 2024 and grow to around 84% by 2030, reflecting both consumer preference and policy support for fully electric vehicles.

PHEVs also see steady growth in absolute numbers, increasing from 980,000 units in 2024 to 1.5 million in 2030. However, their share of total EV sales declines as BEVs scale up more rapidly. The IEA forecast also provide expectations for the sales of FCEVs which remain marginal throughout the period, with sales projected to reach only about 4,400 units by 2030. This trend highlights the strong shift toward BEVs as the leading technology in Europe's transition to zero-emission mobility.

6. CHARGING INFRASTRUCTURE DEPLOYMENT IN THE EU

6.1 INTRODUCTION

The transition to electric mobility in the EU requires a coordinated effort between industry actors, particularly given the complexity of the stakeholder landscape in EV charging. Regulatory intervention plays a significant role, as market forces may not incentivise comprehensive coverage, accessibility, technology standardisation and minimising capital requirements where possible. Two key regulatory frameworks which aim to tackle these challenges are the Energy Performance of Buildings Directive (EPBD) and the Alternative Fuels Infrastructure Regulation (AFIR) (gridX, 2025). Each of these regulatory measures aim to tackle important challenges within infrastructure deployment. Under the EPBD regulations, new residential buildings and those undergoing major renovations must pre-cable at least 50% of parking spots if more than three parking spots are to be available at those buildings. For the remaining parking bays, ducting must be carried out (ICCT, 2024). While the EPBD acknowledges the significant role of private charging and the importance of carrying out installations during the construction or renovation phase, AFIR addresses the availability of public infrastructure and is further investigated in this section.

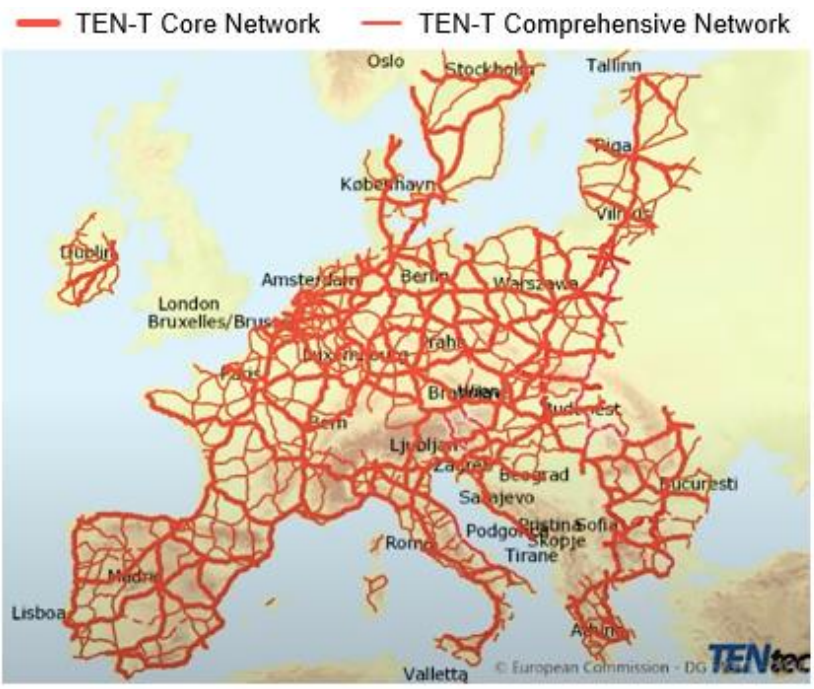
6.2 ALTERNATIVE FUELS INFRASTRUCTURE REGULATIONS AND INCENTIVES

The EU’s Alternative Fuels Infrastructure Regulation (AFIR) is part of the Fit for 55 package which aims to reduce net Greenhouse Gas emissions by 55% by 2030 with respect to emissions in 1990. It is a binding regulation which sets obligatory targets from 2024 on the rollout of recharging and refuelling infrastructure in two key parts: a distance-based target and fleet-based target.

Distance based target

The distance-based target sets requirements for charging hubs or pools along every 60 km of the Trans-European Transport Network (TEN-T) which is a Europe-wide network of roads, rail lines, parts and airports designed to improve transport infrastructure and connectivity across the EU (European Commission, n.d.). The technical requirements of the charging station mandated by AFIR is dependent on the location, specifically whether the site is based on the Core TEN-T network or the Comprehensive TEN-T network as shown in Figure 6-1 below.

Figure 6-1: TEN-T Core and Comprehensive networks in Europe



The Core network includes the most important connections between major cities and nodes, and it is therefore of high strategic importance for the location of publicly available EV charging. It covers 100,000 km, which is more than twice the distance of the 40,000 km comprehensive network that connects all regions of the EU to the core network (ICCT, 2023). Targets for charging hubs are in accordance with the roles of the Core and Comprehensive network, with priority given to the former for the deployment EV charging. For stations situated on the Core network, the total power of charging pools consisting of one or more charging stations must be 400 kW in 2025, with at least one rapid charger rated at 150 kW. By 2027, the charging pool total power must increase to 600 kW with one additional charging station rated at 150 kW. On the other hand, the comprehensive network targets are less stringent. By 2027, the total charging power of hubs on 50% of the comprehensive network must reach 300 kW with at least one charging station rated at 150 kW. By 2035, the electrical output of charging stations per hub on the Comprehensive network must double to 600 kW across 100% of the network. The number of stations rated at 150 kW must also double to two units. Table 6-1 summarises the requirements for infrastructure on the TEN-T network over time.

Table 6-1: Overview of targets for charging pools on Core and Comprehensive TEN-T networks at key timing points

TEN-T Scope	2025	2027	2030	2035
Core	400 kW aggregate charging power and at least one station rated at 150 kW	600 kW aggregate charging power and at least two stations rated at 150 kW	N/A	N/A
Comprehensive	N/A	300 kW aggregate power across 50% of network and at least one station 150 kW	300 kW aggregate power across 100% of network	600 kW aggregate charging power across network and at least two stations rated at 150 kW

Fleet based target

The Alternative Fuels Infrastructure Regulation mandates fleet-based targets for the deployment of public EV charging infrastructure for light-duty electric vehicles, requiring Member States, from 2024 onwards to ensure a minimum of 1.3 kW of publicly accessible charging power per registered BEV and 0.8 kW per registered PHEV in their light-duty vehicle fleet (EUR-Lex, 2023).[18] Member States can request a derogation to lower or end these requirements once the share of battery electric cars and vans on their roads reaches 15% (ICCT, 2023).

National Infrastructure Incentives in Europe

As of 2025, 13 out of 27 EU Member States offer dedicated infrastructure incentives to support the rollout of EV charging infrastructure (ACEA, 2025). These incentives vary widely in form and scope, encompassing direct subsidies for home and public charging stations, tax deductions, and allowances for corporate infrastructure investments. This reflects a clear upward trend: in 2023, only 7 Member States provided such support, rising to 8 in 2024 (ACEA, 2023) (ACEA, 2024). Specifically, public infrastructure incentives have also

[18] Regulation (EU) 2023/1804. Article 3 states: *Member States shall ensure that, in their territory, publicly accessible recharging stations dedicated to light-duty electric vehicles are deployed in a way that is commensurate with the uptake of light-duty electric vehicles and that they provide sufficient power output for those vehicles.*

To that end, Member States shall ensure that, at the end of each year, starting from 2024, the following power output targets are met cumulatively:

(a) for each light-duty battery electric vehicle registered in their territory, a total power output of at least 1,3 kW is provided through publicly accessible recharging stations; and

(b) for each light-duty plug-in hybrid vehicle registered in their territory, a total power output of at least 0,80 kW is provided through publicly accessible recharging stations.

expanded significantly, with only 3 Member States offering them in 2023, increasing to 4 in 2024, and reaching 9 by 2025.

Over this period, the nature of incentives has also evolved; from basic grants for residential chargers to more comprehensive schemes, including accelerated depreciation for businesses and targeted funding for public-access installations. Further information on individual infrastructure incentives can be found on the ACEA's '*Electric cars: Tax benefits and incentives (2025)*' factsheet.

Countries Offering Infrastructure Incentives:

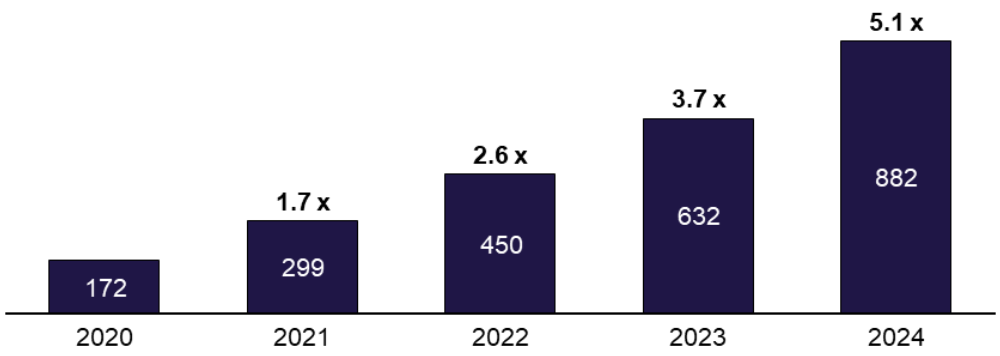
1. **Belgium**: Tax deductions for private and company installations; up to €8,000 for bidirectional chargers.
2. **Croatia**: Co-financing for public and legal entity charging stations (limited funds).
3. **Czechia**: Reduced depreciation period for charging stations; national support for infrastructure development.
4. **France**: The Advenir programme offers €500–€9,000 per charging point depending on location and type.
5. **Greece**: €500 subsidy for wallbox installation.
6. **Hungary**: Full deductibility of charging station costs from corporate income tax for energy suppliers.
7. **Ireland:** Up to €300 for home chargers; up to 70% of costs covered for public infrastructure.
8. **Lithuania:** Up to €1,500 for private and €10,000 for public charging infrastructure.
9. **Luxembourg**: €700–€1,500 for home charging points (up to 50% of cost).
10. **Netherlands:** Grants for entrepreneurs to install public charging infrastructure.
11. **Spain**: Up to 70% of eligible costs covered for individuals and companies under MOVES III-type schemes.
12. **Sweden:** 50% tax deduction for home charging installation; "Ladda bilen" grant for apartment buildings and workplaces.

6.3 STATUS OF CURRENT CHARGING STATION DEPLOYMENT

Deployment of recharging infrastructure for zero-emission cars in the EU

The total number of public EV charging points in the EU grew substantially between 2020 and 2024 (Figure 6-2). By 2024, over 880,000 public chargers were deployed across the region, up from just over 170,000 in 2020, representing over a five-fold increase across the period.

Figure 6-2: Total public EV charging stations at EU level from 2020 to 2024 (thousand units in bar, multipliers with respect to units in 2020 above bars)



Source: EAFO, Ricardo analyses

EV charging power: AC vs DC Chargers

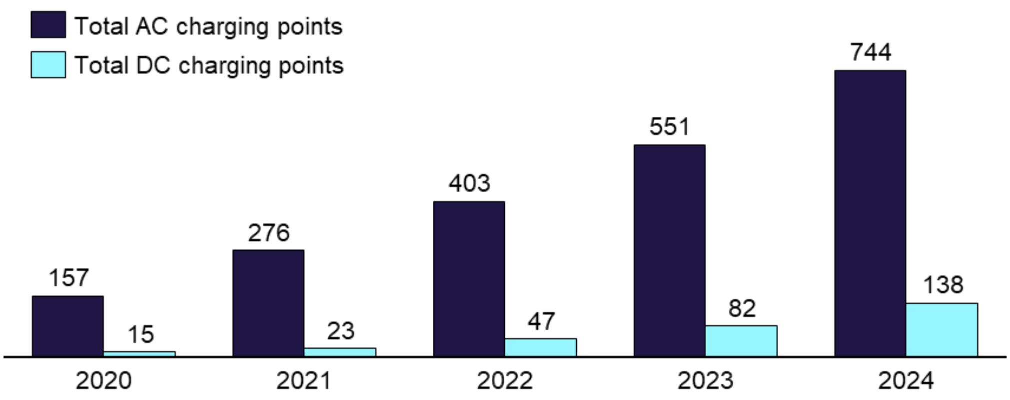
Charging speed – rather than underlying technology – serves as the primary differentiator within EV charging infrastructure. Alternating Current (AC) chargers, typically delivering between 3.7 kW and 22 kW, provide slow to medium charging speeds and are predominantly deployed in residential, workplace, and long-duration public settings. Depending on battery capacity and charger output, charging sessions can range from several hours to overnight (Chargemap, 2025).[19]

Direct Current (DC) chargers are designed for fast and ultra-fast charging, generally starting at 50 kW with higher-capacity chargers exceeding 350 kW. These enable sub-hour charging times, making them ideal for high-throughput locations such as motorways, logistics hubs, and commercial centres.

AC chargers have consistently represented the majority of the EU's public charging infrastructure (ACEA Automotive Insights, 2024).[20] This dominance, particularly of ≤22 kW AC chargers, is driven by cost-efficiency, infrastructure compatibility, regulatory support, and alignment with user charging behaviours. Advantages include minimal impact on local distribution networks, ease of integration with existing electrical systems, and lower capital and operational costs (Versinetic, 2025).[21]

In 2020, there were over 150,000 public AC chargers across the EU, comprising 91% of total installations. By 2024, this figure had risen to over 740,000 units – over a 4-fold increase relative to 2020. While AC chargers still constitute the majority, the share of DC fast chargers has steadily expanded, rising from approximately 15,000 units (9% share) in 2020 to nearly 140,000 units (16% share) by 2024 (Figure 6-3).

Figure 6-3: Overall growth of public EV charging stations at EU level from 2020 to 2024, by power type (thousands)



Source: EAFO, Ricardo analyses

Medium-speed AC chargers (7.4 kW ≤ P ≤ 22 kW) constituted the majority of AC infrastructure in 2024, representing 89% of all AC units - equivalent to over 660,000 chargers (Figure 6-4).

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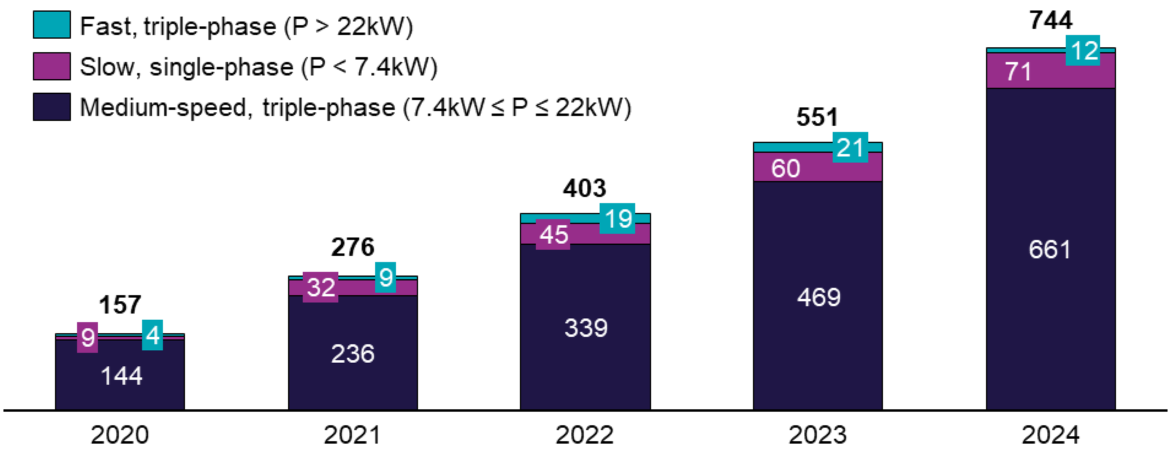
[19] Home and workplace charging commonly use 3.7–7 kW AC; commercial setups may support up to 22 kW where three-phase AC supply is available. DC Fast charging stations convert AC electricity from the grid into DC using a high-power converter and supply it directly to the vehicle's battery, bypassing its onboard charger for reduced charging durations.

[20] EAFO illustrate that approximately only one in every seven chargers (13.5%) was capable of fast charging (charging capacities above 22kW) in 2023, with lower capacity chargers making up the majority of the EU total.

[21] Rapid chargers necessitate higher power delivery capabilities, which can strain local distribution grids. The UK's National Grid estimates that a single 350kW ultra-rapid charger could incur costs up to €1.187 million (£1 million) to install in areas requiring electricity network reinforcement.

Figure 6-4: Overall growth of public EV charging stations at the EU level from 2020 to 2024, split by AC charging speed (thousand units)

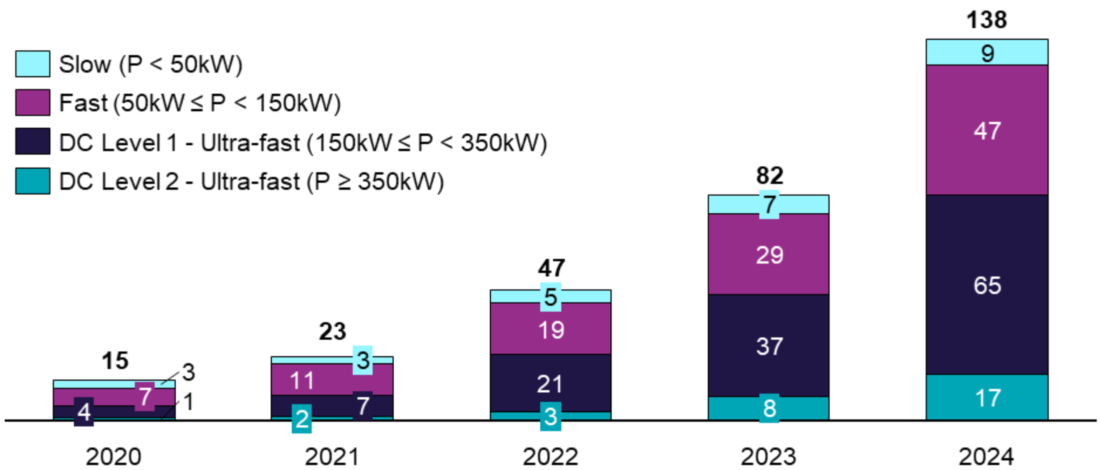


Note: The data indicates a pronounced decline in the number of fast chargers between 2023 and 2024, with reported figures showing an almost 50% reduction. This anomalous trend has been verified and aligns with values published in the source dataset, suggesting that the decrease reflects reported data rather than a processing or classification error.

Source: EAFO, Ricardo analyses

Within the DC segment, 7% of chargers were classified as slow, 34% as fast, and 59% as ultra-fast in 2024. The share of DC ultra-fast chargers has grown significantly, rising from 34% in 2020 to 59% in 2024, driven by increasing demand for high-throughput charging. This growth has come at the expense of both slow (decreasing from 20% to 7%) and fast (decreasing from 45% to 34%) DC chargers (Figure 6-5).

Figure 6-5: Overall growth of public EV charging stations at the EU level from 2020 to 2024, split by DC charging speed (thousand units)



Source: EAFO, Ricardo analyses

Member State-level deployment of public EV charging stations

All EU Member States experienced an increase in public charging stations between 2020 and 2024 (Table 6-2). In 2020, the Netherlands and Germany led the region, with approximately 64,000 and 41,000 chargers, respectively. By 2024, the Netherlands remained the top contributor, reaching around 183,000 chargers. With Germany still second with approximately 160,000 chargers. France sat close behind in third with nearly 156,000 total, with all other Member States reporting fewer than 80,000 total units each. Notably, despite having relatively low absolute numbers, Greece, Lithuania, Estonia and Bulgaria recorded the highest relative growth, with near 20-fold increases in public charger deployment over the period.

Table 6-2: Public EV chargers by Member State in 2020 and 2024

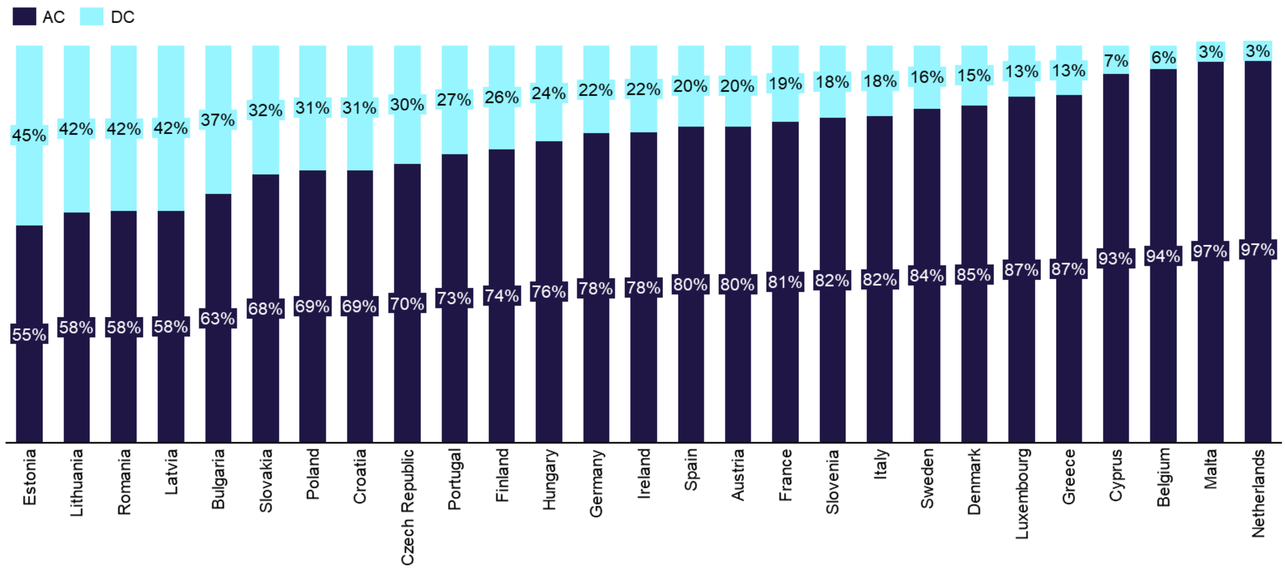
Member State	Public EV chargers in 2020	Public EV chargers in 2024	Growth Ratio Equivalent 2020-2024
European Union	**171,623**	882,012	**5.14x**
Austria	8,104	30,431	3.76x
Belgium	8,003	76,819	9.60x
Bulgaria	161	3,020	18.76x
Croatia	417	1,839	4.41x
Cyprus	46	512	11.13x
Czech Republic	1,031	6,359	6.17x
Denmark	3,547	35,869	10.11x
Estonia	56	1,051	18.77x
Finland	3,642	16,726	4.59x
France	29,000[22]	155,980	5.38x
Germany	41,199	159,958	3.88x
Greece	291	7,049	24.22x
Hungary	1,217	4,175	3.43x
Iceland	386	2,548	6.60x
Ireland	1,065	3,588	3.37x
Italy	11,564	58,189	5.03x
Latvia	266	1,157	4.35x
Lithuania	123	2,947	23.96x
Luxembourg	1,065	2,651	2.49x
Malta	97	120	1.24x
Netherlands	64,457	183,000	2.84x
Norway	13,823	30,224	2.19x
Poland	1,586	9,555	6.02x
Portugal	2,353	12,199	5.15x
Romania	477	4,566	9.57x
Slovakia	425	3,248	7.64x
Slovenia	363	2,156	5.94x
Spain	5,741	45,213	7.88x
Sweden	14,327	53,778	3.75x

Source: EAFO, Ricardo analyses

[22] EAFO data only exists from 2021 Q3 onwards for France. Approximate 2020 value derived from a Gireve report '*National barometer of public charging infrastructure for EVs in France,'* published in December 2022, which outlined that the 77,318 public charging points in France on the 31st of November 2022 represented a 167% increase on the same month in 2020. Source: [Barometer of charging points in France - November 2022 - Gireve]

Figure 6-6 highlights the predominance of AC charger deployment across most EU Member States in 2024. A notably higher penetration of DC chargers is observed in Estonia, Lithuania, Romania and Latvia, where DC chargers account for over 40% of the total public charging infrastructure in each country.

Figure 6-6: Share of AC and DC EV chargers by Member State in 2024



Source: EAFO, Ricardo analyses

Infrastructure deployment in relation to AFIR requirements and projections

EAFO publishes (EAFO, 2025)[23] the progress made by Member States in meeting their fleet-based AFIR targets which was used for the subsequent analysis. In accordance with *Article 3.1* of the Alternative Fuels Infrastructure Regulations (AFIR), the target power outputs for each EU27 Member State illustrated below is calculated by summing the products of the number of registered BEVs and PHEVs with their respective power output requirements mandated by AFIR:

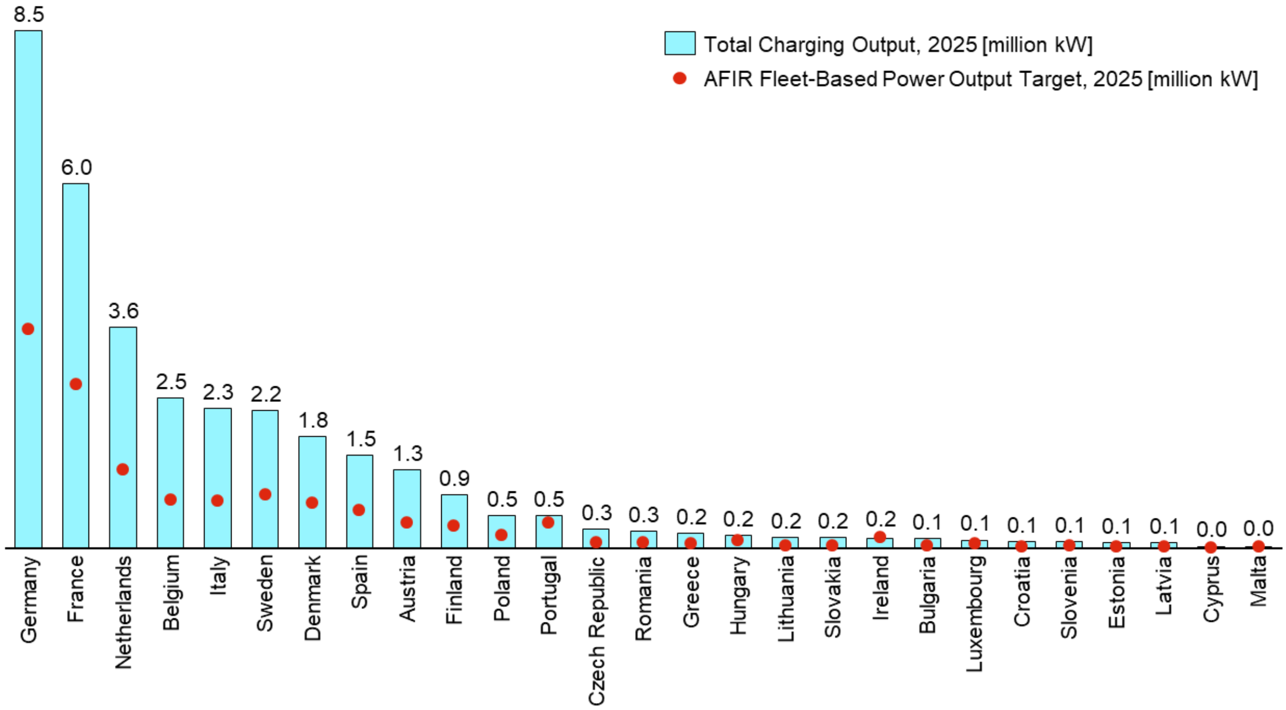
$$Target\ Output = (Number\ of\ BEVs\ \times 1.3kW) + (Number\ of\ PHEVs \times 0.8kW)$$

Figure 6-7 and Table 6-3 present a comparative assessment of Member States' performance against their 2024 AFIR fleet-based charging power output targets, identifying those that meet or exceed the requirements and those that fall short.

As of September 2025, most Member States (25) surpassed their mandated targets. France and Germany recorded the highest absolute deployment levels, each exceeding 6 million kW, followed by the Netherlands with over 3.5 million kW. All three demonstrated surpluses of more than 2 million kW relative to their respective AFIR obligations. Two Member States, Ireland, and Malta did not meet their 2024 fleet-based charging power output targets.

[23] AFIR fleet-based target tracker. Published EAFO data outlines the EU27 Member States' progress towards meeting their fleet-based AFIR targets.

Figure 6-7: Analysis of Member State total charging output against AFIR fleet-based targets in 2025 (million kW).



Source: EAFO, Ricardo analyses

Table 6-3: Member State comparison of actual total charging output with total charging output power per AFIR fleet-based target for the year 2025, as of September 2025. Key: Output Surplus, Output Deficit

Member State	Total Charging Output, 2025 [kW]	AFIR Fleet-Based Power Output Target, 2025 [kW]	Power Output Surplus/Deficit [kW]
Germany	8,482,349	3,389,025	5,093,324
France	5,971,304	2,528,152	3,443,152
Netherlands	3,616,955	1,204,210	2,412,745
Belgium	2,453,460	745,005	1,708,455
Italy	2,281,730	721,710	1,560,020
Sweden	2,247,516	824,378	1,423,138
Denmark	1,832,616	693,941	1,138,675
Spain	1,525,846	576,148	949,698
Austria	1,278,056	390,758	887,299
Finland	868,618	334,153	534,465
Poland	535,104	193,036	342,068
Czech Republic	307,841	80,749	227,093
Romania	276,010	85,455	190,555
Greece	245,371	58,618	186,753
Lithuania	175,940	38,194	137,746
Portugal	522,856	389,301	133,555

Member State	Total Charging Output, 2025 [kW]	AFIR Fleet-Based Power Output Target, 2025 [kW]	Power Output Surplus/Deficit [kW]
Slovakia	165,382	33,367	132,015
Bulgaria	149,035	31,759	117,276
Croatia	107,049	21,747	85,302
Hungary	204,308	120,647	83,661
Slovenia	97,071	30,192	66,879
Estonia	82,662	17,620	65,042
Latvia	78,536	14,326	64,210
Luxembourg	128,754	64,777	63,977
Cyprus	11,747	5,310	6,437
Ireland	160,400	161,252	-852
Malta	1,866	15,007	-13,141

Source: EAFO, Ricardo analyses

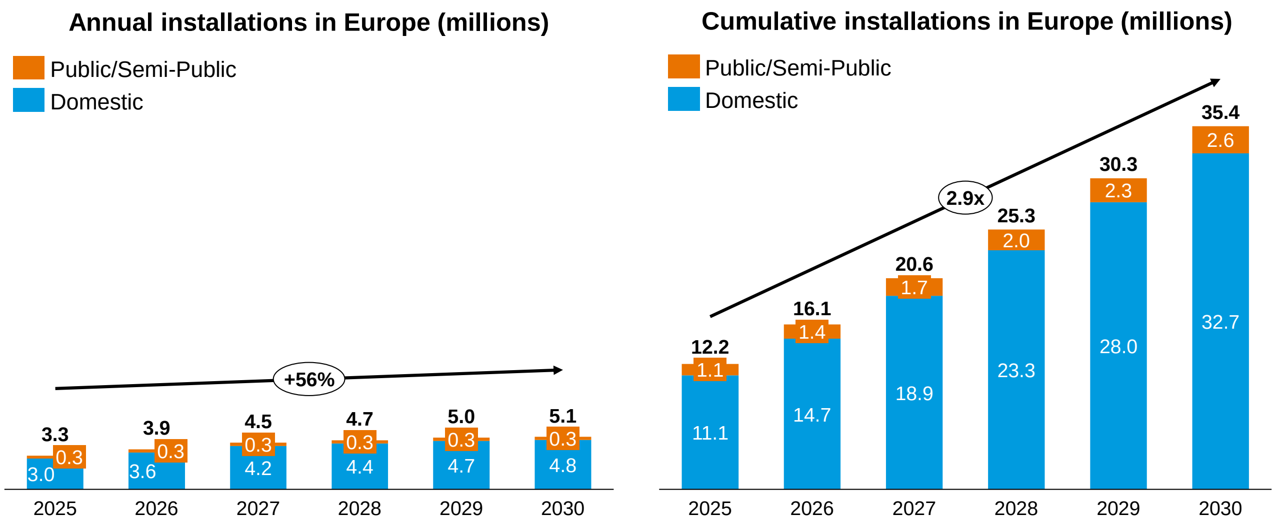
6.4 CHARGING STATION DEPLOYMENT FORECAST

Infrastructure access is a topmost priority of new EV buyers, and this is reflected in policymaker ambitions for the deployment of public infrastructure mandates in AFIR. This section investigates the forecasted availability of European charging infrastructure for private and public use cases with a deeper dive into the expected deployment of public and semi-public infrastructure.

European charging infrastructure growth forecast

Figure 6-8 below shows the annual (left) and cumulative (right) deployment of public/semi-public and domestic infrastructure in the EU between 2025 to 2030 [24]

Figure 6-8 Charging forecast (million units) for domestic and public/semi-public charging infrastructure in Europe. Annual installations - left, and cumulative installations - right.



Source: (S&P Global, 2022)

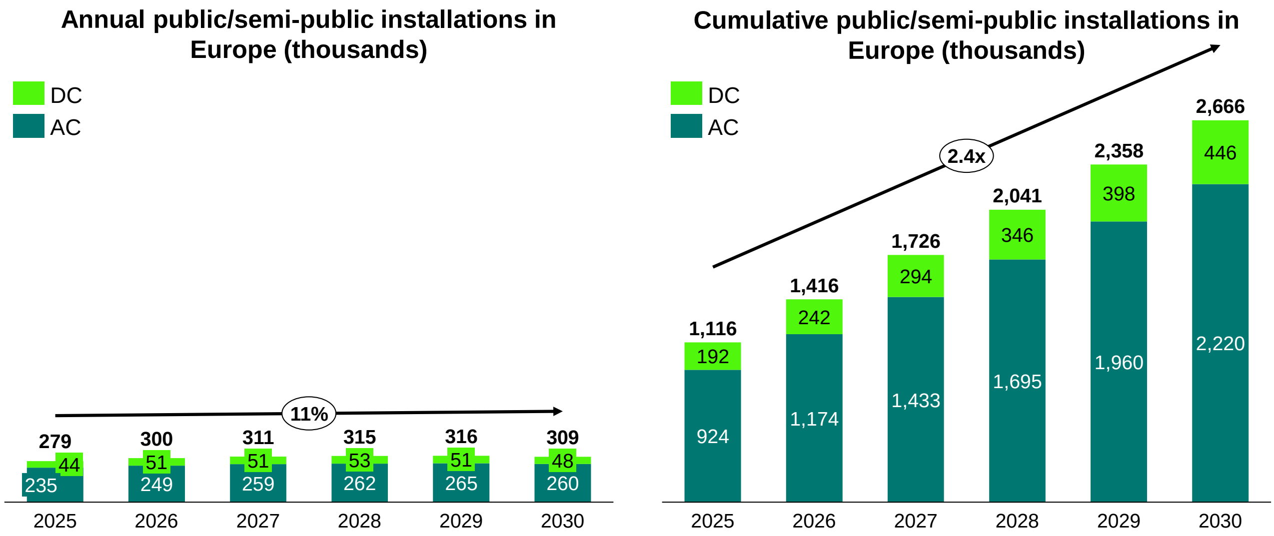
[24] Public/semi-public infrastructure includes OEM specific hardware which is less than 1% of the volumes throughout the forecast period

Annual deployment figures for charging infrastructure are expected to increase from 3.3 million in 2025 to 5.1 million in 2030, representing a 56% increase in yearly installations. The volume of public/semi-public infrastructure deployments per year are expected to remain steady over the forecast period at 0.3 million while yearly private charging deployments will increase from 3 million in 2025 to 4.8 million in 2030. On a cumulative basis, the scale of charging infrastructure will almost triple across the region from 12.2 million in 2025 to 35.4 million in 2030.

Public/Semi-public European infrastructure forecast

Figure 6-9 below further investigates the public/semi-public infrastructure forecast in Europe, split by AC and DC charging stations on an annual (left) and cumulative (right) basis

Figure 6-9: Annual and cumulative deployments of public and semi-public infrastructure in Europe from 2025 to 2030, split by AC and DC charging.

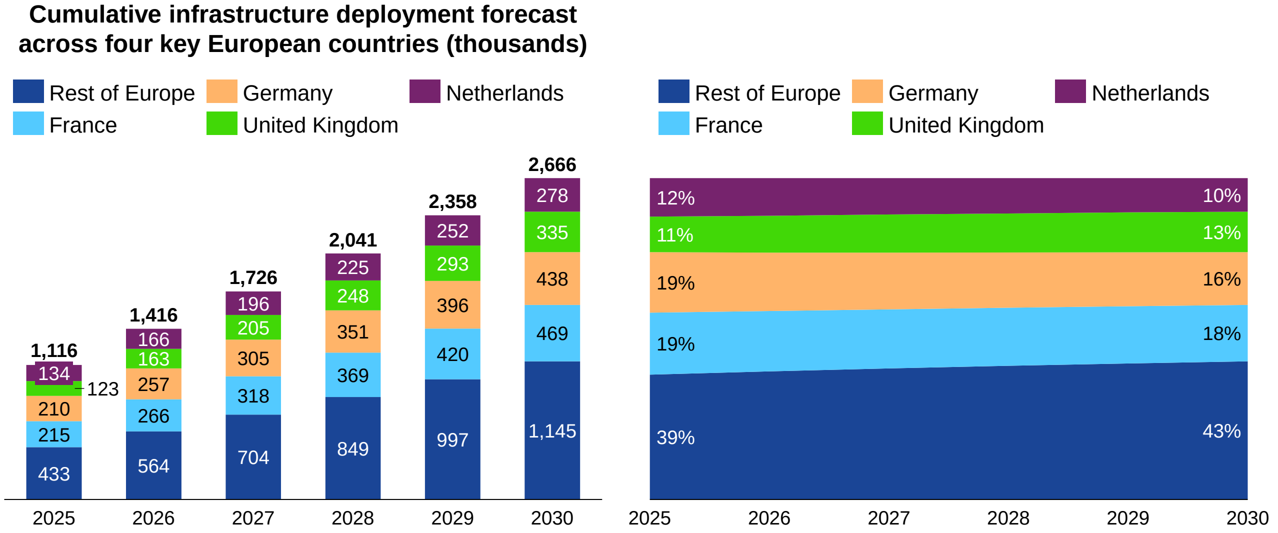


Source: (S&P Global, 2022)

In 2025, 279 thousand public/semi-public charging stations are expected to be deployed in Europe. This is expected to gradually increase year on year to 309 thousand by 2030. Approximately 85% of this infrastructure is expected to comprise of AC charging stations which is not expected to change over the forecast period. In contrast, the total volumes of available infrastructure are expected to see a more significant increase from 1.1 million in 2025 to almost 2.7 million by 2030, representing a 2.4x increase over the forecast period.

Figure 6-10 below further segments the cumulative public and semi-public infrastructure deployments by region.

Figure 6-10: Cumulative deployments of public/semi-public infrastructure in Europe and overall share by country/region.



Source: (S&P Global, 2022)

The figure highlights that France, Germany, Netherlands and the UK are expected to have deployed over 60% of total European public/semi-public infrastructure by the end of 2025. France and Germany each contribute almost 20% of the total charging deployments in the EU, followed by the Netherlands at 12% and the UK at 11%. Over the forecast period the share of deployments by region is expected to remain relatively uniform. Other European countries are expected to gain 4% higher share of the total cumulative deployments by 2030 compared to 2025.

6.5 CHALLENGES IN ACHIEVING COMPREHENSIVE COVERAGE

The European Union's ambition to lead the global transition to electric mobility is a cornerstone of its climate and mobility goals. A robust and accessible charging infrastructure is critical to achieving these objectives, as it underpins the widespread adoption of EVs. However, several persistent and emerging challenges threaten to slow progress and create disparities across Member States. Addressing these challenges is essential to ensure that the EU can meet its decarbonisation targets and maintain its leadership in sustainable transportation.

Infrastructure planning and balancing consumer expectations

Ensuring the right balance between supply and demand is a complex task. The IEA highlights that accurately planning the appropriate ratio of public chargers to EVs is challenging due to varying dynamics across Member States. Furthermore, EY warns that EV production and sales are expected to outpace the deployment of public charging infrastructure in the coming decade (EY, 2023). This growing gap is contributing to "charging anxiety" among consumers and could slow the pace of EV adoption. The issue is not simply the number of chargers, but also their location, visibility, and integration into a broader, user-friendly network. Insufficient infrastructure can lead to user inconvenience and range anxiety, while overbuilding may result in underutilised assets and economic inefficiencies.

Consumer expectations are also evolving. Ricardo's findings show that users prefer faster chargers that are reliable, immediately functional, and easy to access (Ricardo, 2022). Business models must therefore prioritise high uptime and rapid maintenance. Additionally, incentives such as free charging (whether offered by manufacturers or CPOs) can significantly enhance the public charging experience and encourage adoption. Achieving optimal utilization requires careful, data-driven planning that accounts for regional differences in EV uptake, urban density, and consumer behavior.

Uneven coverage and rural inaccessibility

There are significant disparities in the scale and mix of public charging facilities across EU countries. EY points out that the challenge is not binary, whether chargers exist or not, but rather about their strategic placement, revenue potential, and ability to serve diverse user needs (EY, 2023). Some regions benefit from dense, high-speed networks, while others remain underserved, particularly in rural or economically disadvantaged areas.

The availability of home charging is also uneven across the EU. In areas where home charging is limited, such as dense urban environments, public infrastructure plays a critical role. The IEA notes that high coverage of publicly accessible charging is essential in these regions to ensure equitable access and improve the overall consumer experience (IEA, 2024). Without sufficient public infrastructure, EV adoption may be constrained among populations without access to private parking.

Ricardo also highlights the specific difficulties of deploying charge points in rural areas (Ricardo, 2022). Lower EV uptake in these regions leads to lower utilization rates, making them less attractive for CPOs. This creates a cycle of underinvestment and limited access, further entrenching regional disparities in EV infrastructure availability.

7. CONCLUSIONS

This study has shown that the IEC 61851 standards and that the IEC 62196 connector standards are widely used such as Type 2 (AC) and CCS2 (DC) have been fully adopted in Europe. A broad range of communication standards serve a variety of data transmission requirements. ISO/IEC 15118 is a widely used protocol which standardises communications between the vehicle and charging stations. A broader range of open standards are also undergoing continual development upstream of the charging station.

Plug and charge is a functionality which allows automatic identification of vehicles and authorisation of charging upon plugging in. It is expected to enhance the user experience by mitigating common frustrations like carrying multiple charge cards or installing various charging applications.

The Alternative Fuels Infrastructure Regulation (AFIR) sets out charging infrastructure deployment targets for the EU and mandates transparent information at public charging stations, including multiple payment options.

Analysis shows strong compliance with Member State AFIR total charging power output targets in 2024. However, to meet the European EV sales ambitions, it is forecast that the number of public charging installations will also need to approximately treble to 2.6 million by 2030. Research has highlighted significant potential investment barriers including:

- Uncertain rate of EV fleet growth, and hence charging demand and utilisation of infrastructure
- High cost and time for grid infrastructure to support connection to charging points, partly due to processes for the provision of grid capacity which are lengthy, complex and inconsistent across Member States
- Uncertainty about future incentives promoting EV uptake and charging infrastructure development
- Uncertainty regarding the required mix of charger speeds
- Low return on investment for infrastructure in regions of low utilisation required to provide wide network coverage

Understanding consumer preferences and decision-making criteria around public EV charging is critical for accelerating EV adoption and ensuring user satisfaction. EV consumers have diverse needs and decision criteria when it comes to using public charging infrastructure, but convenience and reliability, consistently emerge as top priorities. However, findings highlight consumer concerns over unreliable charging points, wait times, insufficient availability, and inconsistent or unclear pricing information. Users without home charging are disproportionately affected, facing more challenges with availability, affordability and usability of public infrastructure. Price transparency and comparability are lacking, with many consumers unable to compare tariffs or understand charging costs due to inconsistent or incomplete information. In addition, accessibility is a persistent barrier for disabled users, older adults and women who face significant challenges due to poor infrastructure design, safety concerns and lack of inclusive features, despite existing regulations.

AFIR aims to address many of these concerns. The next five years are critical to ensure continued growth of the public charging infrastructure and avoid an implementation gap between the regulatory framework and the reality of public charging point availability to all users.

Policy recommendations include:

- Measures to reduce the cost, time and complexity for high power grid connections to charging infrastructure, including harmonisation of grid upgrading processes and energy billing for EV infrastructure across EU countries
- Continued support for incentives to support EV uptake and infrastructure deployment
- Enforce reliability standards for public chargers including uptime requirements, maintenance response times and clear fault reporting systems
- Strengthen enforcement of AFIR payment rules requiring all public chargers to offer clear, simple and universally accepted ad hoc payment options (e.g. contactless card payments)
- Consumer education – improving awareness of: pricing options; subscription benefits; payment methods; fines of overstaying at charging stations; and available support for new EV users
- Fund inclusive infrastructure upgrades targeting priority user groups (disabled users, women, older adults) through public-private partnerships or accessibility improvement grants

- Provide information on where chargers are located, their status and, where possible, the number of queuing vehicles.

The following points are highlighted from each section of the report

Section 2: Current status in European charging infrastructure

The EU fully adopts IEC 61851 which defines four modes of charging that govern the means of electrical energy delivery from the source to the vehicle. Modes 3 and 4 are the most widespread for AC and DC charging respectively through dedicated charging equipment in private, public or semi-public locations. **Specific connector standards from IEC 62196 are widely used in the EU**, such as Type 2 (AC) and CCS2 (DC). Other connector types are also found in the EU for legacy infrastructure, such as CHAdeMO and Type 3, but these are generally phasing out globally and may create interoperability challenges for vehicles which do not support these connector designs. Further complexities to the connector design landscape include new designs that have the technical potential for higher power charging such as ChaoJi and NACS. While these designs are capable of faster charging times, interoperability challenges must be carefully managed between vehicles and infrastructure through aftermarket adapters or other means.

Communication standards in the charging landscape serve a variety of data transmission requirements across the communication chain. ISO/IEC 15118 is a widely used protocol which standardises communications between the vehicle and charging stations. A broader range of open standards undergoing continual development are observed upstream of the charging station. OCCP is used to define communications between charging stations and the CPO management system. Such systems can interact directly with eMSP platforms with OCPI or through a clearing house using either OCHP, OICP or eMIP.

Plug and charge is a functionality which allows automatic identification of vehicles and authorisation of charging upon plugging in. It is expected to enhance the user experience by mitigating common frustrations like carrying multiple charge cards or installing various charging applications. As of 2024, plug and charge is already in its implementation stage in Europe, available at more than 5,000 Allego charging stations with ambitious plans of rolling out across more than 34,000 Allego stations.

Section 3: CPO/eMSP business models and challenges

Integrated charging providers typically adopt one of three main business models depending on their organisation's objectives, cost constraints, desired level of control in price-setting and involvement in overseeing charging operations. The Network Operator model involves selling hardware to site hosts and earning network fees from them to bill users and manage access, but the site host sets the final charging price. In the Owner Operator model, the company owns the infrastructure, sets the prices, and relies on driver subscription fees and high charger utilisation for revenue. Finally, the emerging Charging-as-a-Service model sees companies offer turnkey solutions to site owners for a recurring subscription fee, removing the burdens of upfront cost and maintenance.

Depending on the objectives of the entity in control of price setting, operators may seek to charge no fee to attract customers to generate revenue for their main business, a nominal fee to recuperate costs for making infrastructure available or generate a profit from the offering. Fee structures for EV charging can be comprised of any three basic building blocks including a combination of; a volumetric fee in which customers are billed per kWh of energy, a time-based fee for occupancy of the parking bay, a flat fee which may be per session, monthly or annual. In 2024, approximately 90% of AC and DC charging stations in Europe utilise volumetric fees, which are most comparable to refuelling a conventional vehicle and therefore easiest for consumers to understand. The remaining 10% includes charging stations which charge based on time, a combination of the three mechanisms, or any other means. Consolidation of the mechanisms by minimising or eliminating the fees other than volumetric pricing is likely to lead to better consumer understanding of the price prior to initiating charging sessions.

Dynamic pricing tariffs are the most commonly used in Europe, with implementation strategies for each bringing unique benefits and challenges. Time of use tariffs adjust pricing according to the time of day with the aim to mitigate demand peaks during hours of typically high demand. However, with higher deployment of BEVs, this strategy can create new demand peaks during hours which are conventionally off-peak. Critical peak pricing mitigates this challenge by using predictions of the load on the grid to adjust tariff levels, but shorter notice periods of price changes creates uncertainty for drivers seeking to charge at times of low electricity prices. Peak time rebate pricing, rather than penalising drivers for charging at times of high demand, provides a reward mechanism to encourage drivers to charge at times of low demand. This approach is likely to get better reception among drivers due to the avoidance of a penalty, but requires more effort from charging providers to build a customer baseline load estimation which will impact their business case. Finally, real-time pricing can be used to adjust pricing in small intervals based on current grid conditions, but, similar to critical peak pricing it results in user challenges to plan their charging events.

Grid constraints and complex permitting processes remain the most significant barriers to charging infrastructure deployment. High costs of grid upgrades, lengthy and inconsistent permitting across Member States, and limited transparency in cost and regulatory procedures delay project rollouts and deter investment. Legacy infrastructure and fragmented energy management systems further exacerbate capacity and efficiency issues. Operational reliability and interoperability challenges undermine service quality. Uptime is impacted by system faults, vandalism, inconsistent reliability standards, and lack of integration across OEMs. Interoperability issues between CPOs and eMSPs hinder real-time energy optimisation, remote maintenance, and seamless user experiences, while protocol fragmentation complicates cross-border service provision. Market concentration and strategic barriers restrict competition and investment efficiency. Exclusive contracts, vertical integration, and dominance by early market entrants can result in exclusionary conduct, limiting site access and innovation. Coupled with uncertainty around optimal charger mix and low utilisation of fast chargers, these conditions create revenue risks and complicate network planning.

Section 4: Consumer perspectives and needs

Convenience and reliability of public charging points are top consumer priorities when using public charging infrastructure. However, users often encounter a range of issues that undermine confidence in the current network, including broken chargers, long wait times, poor location coverage, and unclear pricing. These problems contribute to a widespread perception of public charging as inconvenient and unreliable, leading to user dissatisfaction and charging anxiety. The perception that public chargers are difficult to find, slow or frequently out of order not only frustrates current EV owners, but also discourages potential EV buyers. To support the wider adoption of EVs, it is essential that public charging infrastructure is rolled out more strategically and supported by clear, reliable and user-friendly information. Improving the day-to-day usability and reliability of charging points will be critical to meeting consumer expectations and overcoming barriers to EV uptake.

Users without home charging are disproportionately affected, facing more challenges with availability, affordability and usability of public infrastructure. Wide disparities in the geographic distribution of public charging points remain a significant barrier to equitable EV adoption, especially for households without access to private charging points. In some areas, more than half of EV drivers rely entirely on the public charging network, yet coverage is inconsistent across cities, regions, and countries. Without targeted investment to expand public charging in under-served locations, these infrastructure gaps risk slowing EV uptake and reinforcing inequality in EV accessibility.

Price transparency and comparability are lacking with many consumers unable to compare tariffs or understand charging costs due to inconsistent or incomplete information. Consequently, this inconsistent pricing undermines consumer trust and complicates efforts for consumers to make informed, cost-effective charging decisions. Bridging this gap will require greater coordination across operators to ensure clearer, more predictable pricing structure that reflect consumer needs and usage patters. Without this, cost-related uncertainty will continue to hinder the user experience and deter wider EV uptake.

Payment remains fragmented and confusing, despite AFIR provisions – many CPOs do not clearly communicate accepted payment methods, and consumers are often required to juggle multiple apps or systems. Clearly, there is a lack of harmonisation across operators and poor visibility of accepted payment methods at charging points. Surveys show that few users rely on a single method, and many have experienced problems such as failed transactions, poor connectivity, or being forced to download a new app at the point of use. While roaming has helped improve cross-border charging, domestic payment remains a persistent source of friction. The growing reliance on RFID cards, limited adoption of discounted tariffs, and low consumer awareness of available options suggest that better standardisation, clearer communication from charge point operators, and targeted consumer education are essential to improve payment accessibility and ensure a smooth charging experience.

Accessibility is a persistent barrier – disabled users, older adults, and women face significant challenges due to poor infrastructure design, safety concerns, and lack of inclusive features, despite existing regulations. Despite existing EU legislation mandating accessible public charging infrastructure, recent evidence highlights a persistent and concerning gap between policy intent and real-world implementation. Many disabled users, older individuals and women continue to face significant barriers to using public EV chargers – from poor physical design, heavy or awkward cables, and inaccessible interfaces to safety concerns caused by inadequate lighting or isolated locations. Surveys consistently found that a majority of disabled users find public charging infrastructure inaccessible, with some deciding against EV ownership altogether as a result. These challenges are compounded by the wider built environment, which often lacks features such as dropped kerbs, clear signage, or weather protection. Without urgent and practical improvements that prioritise inclusive design and enforce existing accessibility standards, large segments of the population risk being excluded from the transition to electric mobility.

Section 5: EV market outlook

New zero-emission passenger car registrations increased seven-fold between 2019 and 2023, reaching ~1.5 million units in 2023. PHEV registrations peaked at ~0.9 million in 2022, before declining through 2024. The combined market share of BEV and PHEV new registrations rose from 3% in 2019 to 22% in 2023, before contracting to 21% in 2024, suggesting early signs of market plateauing.

The EU BEV fleet expanded more than nine-fold from ~0.6 million in 2019 to ~5.8 million in 2024. The PHEV fleet grew eight-fold over the same period, from ~0.5 million to nearly 4 million. Despite rapid growth, BEVs and PHEVs combined account for only ~4% of the EU passenger car fleet (~250 million), highlighting the slow pace of fleet turnover.

Between 2019 and 2024, Denmark, Sweden, Finland, and Belgium recorded the highest increases in battery-electric vehicle (BEV) market share for new registrations, with respective growth rates of +50%, +31%, +28%, and +27%. The leading countries in plug-in hybrid electric vehicle (PHEV) market share growth over the same period were Sweden (+17%), Finland (+15%), and both Belgium and the Netherlands (+13%).

In terms of BEV fleet share growth between 2019 and 2024, Denmark saw the most significant increase at +11%, followed by Luxembourg and Sweden with +7% each, and the Netherlands at +5%. PHEV fleet share growth was highest in Sweden and Belgium (both +5%), with Denmark and Finland each reporting a +4% increase. The EU27 Member States that saw the greatest absolute growth in total ZLEV fleet size between 2019 and 2024 were Germany (+2.4 million vehicles), France (+1.7 million), the Netherlands (+0.7 million), and Sweden (+0.6 million).

EU Member States use a mix of taxation measures, subsidies, and other financial incentives to reduce the cost of EV ownership and support the transition to zero-emission transport. As of 2025, all 27 Member States offer taxation measures, 19 offer subsidy incentives and 14 offer other incentives. Taxation strategies vary by country, with common examples including tax exemptions for ZEVs, linking the tax amount with the vehicle tank-to-wake emissions or lowered tax for vehicles with larger battery size, cost and emissions. Subsidy incentives prominent in Europe include direct subsidies for the purchase or lease of ZEVs for companies and private households. Operational subsidies are also used, such as subsidised costs per kWh recharged. While these measures motivate potential buyers to switch to ZEVs, the premature removal of financial incentives prior to reaching a critical mass can result in scepticism among drivers, as recently observed across the European market.

Section 6: Infrastructure

AFIR is a binding regulation which sets obligatory targets from 2024 on the rollout of recharging and refuelling stations in two parts. The distribution of infrastructure and overall available capacity are two important criteria which determine the success of the e-mobility transition which are tackled by the distance-based target and fleet-based target respectively. The distance-based target ensures breadth of network coverage, by ensuring charging pools are situated along every 60 km of the TEN-T network. Specifications of the pool such as the total power capacity and the power output of the highest rated charging station within the pool must improve over time in accordance with specific targets depending on whether the pool is on the Core or Comprehensive network. A fleet-based target requires that the total charging capacity available in Member States increases with the number of registered electrified vehicles. For each BEV, 1.3 kW of charging capacity must be made available, while for each PHEV, 0.8 kW of charging capacity must be made available. These targets apply until the share of battery electric cars and vans on the roads reach 15%, at which point the Member States can request a derogation to lower or end the targets.

Public EV chargers in the EU increased from ~170k in 2020 to nearly 850k in 2024 – a near five-fold increase. AC chargers (≤ 22 kW) remain the backbone of public charging infrastructure, accounting for over

700k units in 2024 (82% share), up more than four-fold since 2020. Medium-speed AC units (7.4 - 22 kW) represent 89% of all AC chargers. DC charger deployment expanded from ~15k in 2020 to over 130k by 2024 (15% share). Ultra-fast DC chargers (≥ 150 kW) now constitute 59% of all DC units, up from 35% in 2020.

The Netherlands (~177k), France (~154k) and Germany (~148k) lead the EU27 in charger deployment as of 2024. Greece, Lithuania, Bulgaria, and Estonia recorded the highest relative growth in charge point deployment between 2020 and 2024, with public charging infrastructure expanding by nearly twenty-fold. DC chargers make up over 40% of the total stock in Bulgaria, Estonia, Latvia, Lithuania and Romania. 25 out of 27 EU Member States have already exceeded their 2024 fleet-based AFIR power output targets (with only Ireland and Malta lagging). France, Germany and the Netherlands led in absolute output deployment, each with surpluses of over 2 million kW.

Over the next 5 years, the deployment rate of charging infrastructure in Europe across domestic and public/semi-public charging will increase from 3.3 million stations per year in 2025 to 5.1 million stations per year in 2030. The rate of increase is expected to be attributed to faster deployment of domestic charging which will increase from 3 million to 4.8 million over the same period. In contrast, the rate of public and semi-public infrastructure deployment is expected to remain relatively stable at 0.3 million stations per year.

In cumulative terms, the total infrastructure available in Europe is expected to see a near three-fold increase from 12.2 million stations in 2025 to 35.4 million in 2030. By the end of the forecast period, 32.7 million stations are expected to be domestic charging stations while the remaining 2.6 million are expected to be available for public and semi-public use. Further analysis of the public and semi-public infrastructure indicates that AC charging stations are expected to total 2.2 million by 2030 while DC charging stations will total close to half a million in the same timeframe. A majority of the total public and semi-public infrastructure is available in France, Germany, UK and Netherlands and is expected to remain the case to 2030. However, some reports warn of EV sales and uptake outpacing infrastructure deployment. The volume of charging stations required for an e-mobility transition must be placed strategically to distribute charging station facilities. Low EV uptake in rural areas weakens the business case for infrastructure placement for CPOs and creates a cycle of underinvestment and limited access.

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