Policy Brief on Public Charging Infrastructure

Promoting successful roll-out strategies and business models

International Energy Agency

INTERNATIONAL ENERGY AGENCY

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 31 member countries, 10 association countries and beyond.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea
Lithuania
Luxembourg
Mexico
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA

IEA association countries:

Argentina
Brazil
China
Egypt
India
Indonesia
Morocco
Singapore
South Africa
Thailand

International Energy Agency
Website: www.iea.org

Abstract

The International Energy Agency prepared this report, within the framework of a Global Environment Facility (GEF) programme aimed at supporting low- and middle-income economies in their transition to E-mobility. It is the first deliverable of Working Group Four on Charging, Grid Integration, Renewable Power Supply and Battery Re-use, Recycling and Safe Disposal. Its objective is to provide policy makers with a comprehensive overview of the ecosystem of public charging infrastructure (defined as infrastructure that is publicly accessible), as well as key recommendations for its efficient deployment. Although it focuses on charging systems for light-duty vehicles, the report also discusses implications for two- and three-wheelers, as well as heavy-duty vehicles. The findings summarised here are informed by the many contributions and insights provided by international stakeholders. The IEA's analysis begins with a definition of charging infrastructure and describes the different business models associated with it. We present a number of policy examples and conclude with five key recommendations for ensuring the efficient roll-out of public charging infrastructure.

Acknowledgements, contributors and credits

Julia Guyon was the lead author of this report, under the guidance of Alejandro Hernandez Alva – the IEA's Head of the Renewable Integration and Secure Electricity Unit – and Jacques Warichet. Her colleagues Juha Koykka, Luis Lopez and Woan Ho Park also contributed to the analysis. Keisuke Sadamori, Director of the Energy Markets and Security Directorate provided valuable feedback. Valuable comments and feedback were provided by Ekta Meena Bibra, Insa Handschuch, Britta Labuhn, Leonardo Paoli, Apostolos Petropoulos, Alison Pridmore, Cornelia Schenck, Jacob Teter and Per-Anders Widell.

Nicola Clark edited this report. Thanks go to the Communications and Digital Office (CDO) – especially to Jad Mouawad, Head of CDO, and Astrid Dumond, Grace Gordon, Allison Leacu, Jethro Mullen, Julie Puech, Taline Shahinian, and Therese Walsh – for their help with production and for providing website materials. Anna Kalista also provided essential support.

An online seminar on public charging infrastructure deployment strategies and business models was held on 8 December 2021. The participants offered valuable insights and feedback for this analysis. Further details are available at https://www.iea.org/events/public-charging-infrastructure-deployment-strategies-and-business-models.

The authors are grateful for the comments and feedback from many external experts, including Helmer Acevedo (ICCT), Federico Arismendi (IIE-FING-UdelaR), Andres Barentin (ALAMOS), Annika Berlin (UNEP), Dan Bowermaster (EPRI), Francisco Cabeza (Element Fleet Management), Pamela Chiang (ADB), François Cuenot (UN), Pedro Filipe (MAAC Portugal), Aaron Fishbone (GreenWay), Gabriel Guggisberg (AgenciaSE), Harini Hewa Dewage (GEF), Gustavo Jiménez (E-Mobilitas), Josemaría Jiménez (E-Mobilitas), Herman Kwoba (GIZ), Oliver Lah (UEMI), Mattia Marinelli (DTU), Emilie Martin (UEMI), Sajid Mubashir (Department of Science and Technology, Government of India), Hiten Parmar (uYilo eMobility Programme), Lucija Rakocevic (Th!nk E), Sacha Scheffer (Rijkswaterstaat), Sudhendu Jyoti Sinha (NITI Aayog), Urska Skrt (WBCSD), Tali Trigg (EBRD), Christelle Verstraeten (ChargePoint) and Lulu Xue (WRI).

The report was prepared by the International Energy Agency as the first deliverable under the Global E-Mobility Programme funded by the Global Environment Facility (GEF). The work could not have been achieved without the financial support provided by GEF and with the input from many of the partners and experts highlighted above In particular, we would like to acknowledge the UN Environment as the lead implementing agency under the Programme and all their efforts with coordinating the preparations, planning and roll-out of its activities.

Comments and questions on this report are welcome and should be addressed to gef.emobility.wg4@iea.org.

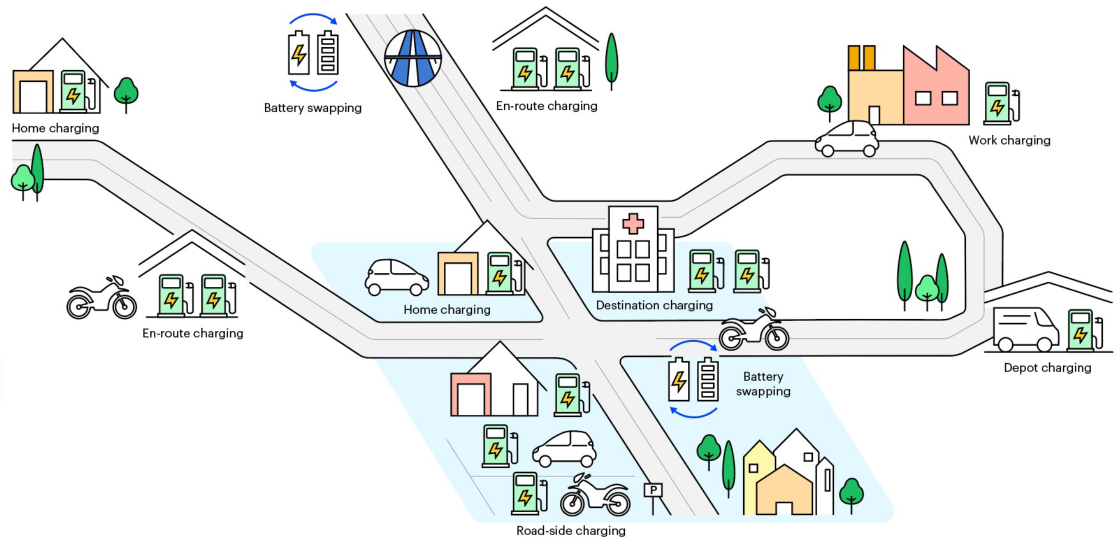
Executive summary

Road transport is responsible for 18% of the global CO_2 emissions from fuel combustion – which makes decarbonisation through electrification of this sector one of the key levers on the pathway to net zero. Given that the electric power sector is the first to decarbonise under the IEA Net Zero Emissions by 2050 Scenario (hereafter, "Net Zero Scenario"), speeding the transition to electric vehicles is vital to achieving this outcome. A successful deployment of electric vehicles requires sufficient and reliable charging infrastructure. Policy frameworks that are appropriate for the local circumstances will support this roll-out in advanced and emerging economies.

"Range anxiety" – the fear of not being able to reach one's destination – is one of the main concerns that drivers have when considering the purchase of an electric vehicle (EV). To ensure the swift adoption of EVs, policy makers therefore need to ensure that sufficient, reliable and easy-to-use charging infrastructure is available. Experience has shown that perceptions about charging infrastructure availability correlate positively with electric vehicle adoption. Other benefits of a ubiquitous charging network include avoiding gaps in charging access and the reduced pressure on increasing battery sizes.

Options for EV charging are diverse, creating many opportunities. Electric vehicles can be charged at any number of locations and without supervision – in contrast to conventional internal combustion engine vehicles, which can only refuel at service stations.

Charging infrastructure solutions



Note: This figure includes both privately and publicly accessible charging locations.

EV charging can occur at different moments in the driver's journey – at home, at work, on the road, or while shopping. For some vehicle models, the discharged battery can also be exchanged for a charged one at a battery-swapping station. With such a variety of options, charging can be readily adapted to suit different use cases.

However, there is no "one size fits all" solution: the diversity of EV charging systems, both in terms of location and charging speeds, also explains the wide variety of business models and roll-out strategies. The most efficient solution will depend on the situation, the type of vehicle, and the driver profile. Policy makers should consider the driving habits and needs of constituents in their jurisdiction before elaborating a strategy for deploying charging infrastructure. Important considerations include: Household living arrangements; rural versus urban structures; traffic patterns; plans for future road infrastructure; the profiles of early EV adopters; the types and uses of vehicles already on the roads; the capacity and connectivity of the existing power grid; the availability of renewable electricity; and the deployment stage of EVs. All these factors will have a significant influence on decision making and should be used to tailor to use cases.

Recommendations for an efficient infrastructure roll-out

Since utilisation rates are likely be low in the early deployment stages, policy makers at every level have a crucial role to play in helping reduce range anxiety and encourage market-driven solutions for installing the charging network. Facilitating communication with the public; issuing mandates and regulations to suppliers, contractors, utilities and other stakeholders; organising public tenders; offering financing or loan guarantees; making public land available for charging sites; as well as upgrading and extending the power grid are just some of the policy instruments at their disposal.

Our report lays out **five key recommendations** to policy makers to ensure that the deployment of public EV charging infrastructure goes as smoothly and as efficiently as possible. They are discussed in detail below, but in summary we advise the following:

Break down the silos: Institutional structures need to be re-thought and re-organised to foster discussions on EV charging infrastructure across sectors (power, transport and urban planning). Dialogue between institutions and jurisdictions needs to be encouraged. Designated contact people need to be assigned to manage Electric Vehicle Supply Equipment (EVSE) installation processes and staff need to be provided sufficient resources and training.

Tailor your strategy: Collect relevant transport and associated data to obtain a clear picture of your jurisdiction. Identify the EV types and users that have the strongest presence and needs. Encourage shifts toward shared transport modes and infrastructure and then incorporate the impact of this on EV charging requirements.

Showcase EV charging as a political priority: Attract private investment by signalling that the transition to EVs is at top of your agenda. Facilitate communication between stakeholders and streamline and clarify your permitting processes.

Encourage standardisation: Make sure that users have access to transparent and reliable information about charging stations and pricing. Ensure a high quality of charging service by integrating performance requirements into your public tenders and support measures. Encourage interoperability across competing charging networks through common technical standards and roaming agreements.

Future-proof your infrastructure: Carefully consider your targets for the future fleet and other transportation strategies and build them into your planning. Promote “smart” metering and smart charging. Ensure that the charging networks built out today are sufficiently adaptable and scalable for your needs down the road. Ensure that the EV charging solutions you adopt favour the use of low-carbon electricity.

Context

Electrification is a key lever on the pathway to net zero

The road transport sector – which represented 18% of the world's emissions from fuel combustion in 2019 – is crucial to government efforts to decarbonise their economies – and E-mobility is an important component of the energy transition. In the IEA Net Zero by 2050 Scenario, electric power generation will be the first energy-related sector to entirely decarbonise – by 2035 in advanced economies and by 2040 globally. Electrifying road transport is therefore the main lever for emissions reduction in that sector. Under the Net Zero Scenario, more than 60% of global sales of new passenger cars will be electric vehicles[1] by 2030. By 2035, there should be no more internal combustion engine (ICE) cars being sold. By 2050, most of the fleet of light-duty vehicles (LDVs) as well as two- and three-wheeled vehicles should be fully battery powered, apart from a few hydrogen-powered vehicles. As for heavy-duty vehicles (HDVs), more than 60% should be battery electric vehicles (BEVs).

Sales of electric passenger car sales reached 6.6 million in 2021, and there are now more than 16 million electric cars registered globally. Yet despite this success, electric cars still represent just 1% of the total global fleet. Clearly, there is much work still to be done to accelerate the adoption of electric cars, two- and three-wheelers, trucks and buses. The deployment of appropriate infrastructure, and integrating those charging networks within the broader electricity grid, are among the first challenges to address.

[1] EVs include battery electric vehicles (BEVs), plug-in hybrid electric-gasoline vehicles and plug-in hybrid electric-diesel vehicles.

Charging infrastructure characteristics

"Range anxiety" needs the full attention of policy makers

In recent driver surveys conducted across Europe and South East Asia, one of the main reasons cited for resisting the switch from ICEs to electric vehicles is the perception that there are not enough charging stations available. The fear of not being able to re-charge in time to reach one's destination – referred to as "range anxiety," remains one of the key barriers to EV adoption. Studies have shown a positive correlation between public charging infrastructure availability and EV adoption: One analysis of the Chinese market suggests that investing in charging infrastructure is four times more effective in increasing uptake than providing consumers with EV purchasing subsidies.

In most developed markets today, the bulk of passenger EV charging – 50% to 90% of all charging sessions – takes place at home. Nonetheless, regardless of the market share of EVs, a minimum level of coverage by public electric vehicle supply equipment (EVSE) is a necessity for a number of reasons. Residents of multi-unit dwellings, for example, do not always have access to private parking with access to a power source. Drivers of commercial vehicles and taxis require charging during their journeys, as do drivers making longer trips for tourism or other purposes. Intervention by policy makers is critical to address potential gaps in charging access and to ensure that charging coverage is not limited to high-use areas.

Ensuring sufficient charging capacity also mitigates the need for manufacturers to equip their vehicles with large batteries. In response to drivers' concerns about long-range journeys automakers have taken advantage of developments in battery technology and declining battery prices to increase the size of EV batteries. These larger power supplies have extended the average range of light-duty electric vehicles to 314 km with a 60 kWh battery. They can now travel up to 640 km on a 108 kWh battery. A two-wheeled electric scooter with a 4 kWh battery can reach distances of up to 180 km per charge. Yet the average distances driven by most drivers are short. In Indonesia, for example, the average daily travel distance (private and commercial vehicles combined) for an ICE vehicle is just 62.6 km. In India, the average for private LDVs and two-wheelers is 40 km per day; commercial LDVs average 100 km and three-wheelers 120 km. In Mexico, drive distances average 47 km for private LDVs, 62 km for commercial LDVs and

28 km for two-wheelers. Long-range drives remain the exception. Similar data collected from the United States and Japan show average daily driving distances below 100 km. While commercial vehicle driving patterns can vary significantly depending on their usage (urban last-mile delivery, long-distance trucks or as company vehicles, for example), the data above and a study on driving patterns in European cities shows that commercial vehicles do make longer average trips than private ones. The data also show that charging time also has a greater impact on commercial drivers since this can affect business operations. A study of German fleets that looked at the relationship between battery size and fast-charging infrastructure showed that only 40% of the commercial vehicles analysed (vehicles with a battery size of 24 kWh) were able to complete their mission without disruption in the absence of a fast-charging infrastructure. But when a fast-charging infrastructure was combined with a battery range of 250 km (a lower threshold than today's average for LDVs), the completion rate rose to 75%. This indicates that battery sizes of both commercial and private vehicles could be better optimised if adequate charging infrastructure were available.

Battery size optimisation is an important factor because the battery represents a large part of the EV's costs, weight and resource intensity. Expanding battery capacity increases an EV's weight which in turn has a negative impact on the vehicle's efficiency and its non-exhaust emissions such as those resulting from tyre wear. Reducing a battery's size could have significant benefits, both economically (the price of the vehicle) and on the sustainability of the EV. Indeed, today's electric vehicles run with lithium-ion batteries, which contain several minerals such as lithium, nickel, cobalt, manganese, graphite and copper – the mining of which is very energy-, land- and water-intensive. To supply the electric vehicle stocks needed in its Net Zero Scenario, the IEA expects overall mineral demand to increase by 30 times the 2020 level in 2030. Finding ways to address range anxiety by improving the charging infrastructure coverage is one important way to reduce the size of EV batteries – lowering the environmental impact of EV production and reducing their cost to consumers.

Location and accessibility define the potential use cases

We define public charging infrastructure based on its accessibility. We thereby distinguish publicly accessible and privately accessible charging equipment. From an electricity grid perspective, there is no difference between the two. However, the way the charging infrastructure is accessed defines its usage – and, by extension, the kinds of business models available. Furthermore, public and private EVSE are often treated differently in legal documents and charging prices per kWh can also differ noticeably between the two.

It is not always easy to differentiate between public versus privately accessible infrastructure. Many reports and position papers even mention a third category – limited publicly available infrastructure – to account for charging stations that are not always available to the public. The term usually denotes charging stations with public access, but which are situated on private property where access and operating hours are restricted. For the purposes of this report, references to "public" charging infrastructure will refer to its accessibility and not to its ownership, and will include limited publicly available infrastructure.

Furthermore, when discussing charging infrastructure for electric vehicles, one can differentiate between charging stations and charge points. A charging station can have several charge points. A charge point can have several charge outlets, but only one of these outlets can function at a time.

Policy makers should clearly define the characteristics of public charging infrastructure and the requirements associated with it, especially if this is linked with public support. For example, in the government of India's guidelines for charging infrastructure for EVs, a public charging station is defined as "an EV charging station where any electric vehicle can get its battery recharged." Specific requirements and rights are detailed within the guidelines. In Germany, all publicly accessible charging infrastructure – defined as infrastructure that can cater to all categories of users, regardless of whether prior registration is required – must comply with specific technical requirements. In addition, every station installed needs to register with the German Federal Network Agency.

Policies for public charging infrastructure and accessibility of private charging infrastructure influence each other: the more private infrastructure there is available, the less demand there may be for public charging facilities. Therefore, policy makers are encouraged to plan for development of both streams simultaneously.

Further categorisation of charging infrastructure is done by location, where one can distinguish home charging, work charging, road-side charging, destination charging, depot charging and enroute charging.

Charging infrastructure definition by location

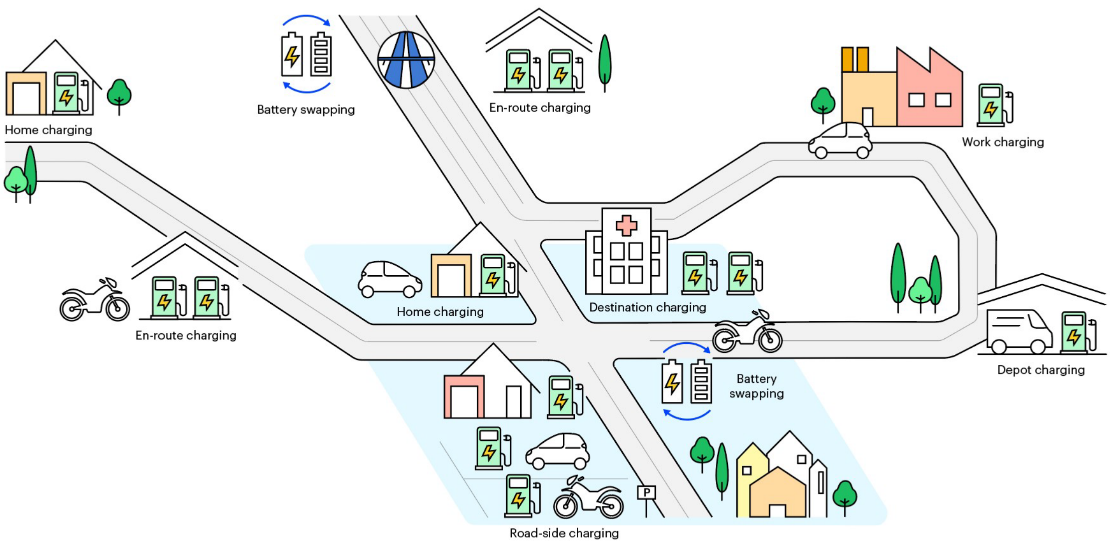
Name	Definition
Home charging	Charging at the driver's residence
Work charging	Charging at the driver's workplace
Depot charging	Centralised charging of commercial fleets, buses or trucks in a building with restricted access fitted out with several charge points

Name	Definition
Road-side charging	Charging at a public or private parking place next to the road, most often in a city or urban environment
Destination charging	Charging at a place of interest (shopping mall, restaurant, public institution…), the destination of a journey, outside of work and home
Enroute charging	Charging at a charging station on the way to the destination, on a highway or travel corridor

An alternative type of charging solution is battery swapping, which consists of removing the discharged battery from the vehicle and replacing it with a fully charged one, at a designated swapping station. Battery swaps can be done manually or mechanically, depending on the battery's size and weight. Such stations can be located at any publicly accessible location. While the availability of this model is currently limited, it is gaining traction in East Africa, for example, for commercial two-wheelers, as well as for two- and three-wheelers in Chinese Taipei and India. The merits and disadvantages of this approach are discussed later in this report.

Other solutions such as charging-while-driving (via induction or catenary) are not addressed in this policy brief as their technological readiness is less advanced than the other solutions mentioned here.

Charging infrastructure categories and respective locations



Note: This figure includes both privately and publicly accessible charging locations.

It is important to make sure that public charging infrastructure, which costs money, resources, and space, efficiently addresses the needs of its users and provides non-discriminatory access to every driver. Ease of use, interoperability, pricing transparency and the use of collected data, as well as hardware and software standardisation, are also points that should be investigated.

The diversity of charging options means a wealth of opportunities

Charging an electric vehicle can be done at various locations, and under various circumstances. Just as ICE vehicles are typically refuelled at service stations, EVs can be quickly re-charged at a fast charge point. But unlike conventional vehicles, they can also be left to charge unattended – in the same way that a mobile device can be plugged in at work, at home, or while running errands or taking part in leisure activities. For some EV models, a discharged battery can also be exchanged for a fully charged one at a battery swapping station. Some charging solutions are more appropriate for certain electric vehicle types than others (fast-charging stations, for example, may be less interesting for two-wheelers).

All these options currently co-exist and are complementary. This is a reflection of how new the EV market is. Such a wealth of choice offers significant flexibility to EV drivers with different needs and profiles. While the "mobile phone charging" model might be best suited for certain use cases, such as private daily commutes, the "service station model", or a solution with battery swapping, might appeal more to commercial EV users or even leisure drivers on longer journeys.

User choice and convenience could play a strong role in determining the best solution. In major EV markets today, home charging prevails – mainly because EV drivers tend to own their own parking space, making this the most practical and affordable option. But this pattern could shift as EV uptake, availability and affordability of fast charging stations increases. Growing demand from commercial and individual drivers whose businesses or residences are not equipped with charging capability could lead to increased utilisation of public EV charging.

Meanwhile, as electric vehicle use and demand for charging infrastructure increase, policy makers will be faced with a choice of whether to invest in more fast-charging hubs or in slow chargers at parking spots. While the first option can serve a greater number of users – thanks to shorter charging times – it is more expensive and requires higher grid capacity. The second requires that vehicles stay plugged in for longer, thereby increasing the spatial footprint of EV charging. This makes it suited for overnight parking and increases opportunities for so-called "smart" charging, where energy consumption can be optimised based on the availability and price of low-carbon electricity – thereby easing grid integration.

Deployment and business models

Several business models exist for public charging infrastructure, reflecting the different use cases

Installing and operating public charging infrastructure involves stakeholders from the energy, transport and real-estate sectors. For the business model to succeed, stakeholders' roles must be clearly defined and considered: Who is the landowner? Who operates the station? Who invests in it and how will revenues be created and split? Who are the clients? Which type of charger will be installed and why? What are the costs and opportunities related to the grid interface?

How charger location affects business models

	Road-side charging	Enroute charging	Destination charging	Shared home or work charging	Battery swapping
Type of charger*	All charger types possible: Slow for overnight or longer duration parking Fast hubs in cities	Fast or ultra-fast chargers	All types possible, depending on dwell time at destination	Primarily slow charging	No plug-in of the vehicle. Batteries can be charged on or off site
Motivations for installation	Complement or replace home charging Diminish coverage gaps Address a wider set of use cases	Long-range journeys Tourism	Attracting business to destination Additional revenue from users Tourism	Revenue and employment generation Efficient use of existing infrastructure	Reducing charge times Allowing swaps at off-grid locations Quicker battery maintenance
Grid connection	Limits the power available, but can be enhanced by on-site storage or grid upgrades				Not obligatory at swap site

	Road-side charging	Enroute charging	Destination charging	Shared home or work charging	Battery swapping
Grid services	Possible, especially for longer dwell times	Limited, since emphasis is on charging speed	Possible, depending on dwell times	Possible	Possible at the charging site
Ownership models	Owner-operator External operator	Concession	Leasing	Owner operates charge point	Usually owner-operated
Business model examples	Sweden's utility charging roads	France's tendering process for highway charging infrastructure	Turnkey charging as a service for businesses	Community charging via sharing apps	Car makers include swappable battery in EV design and build/operate swapping stations

* Slow chargers are defined as having power of up to 22 kW. Chargers with power above this level are considered fast.

Note: Depot charging has not been included in this table because it is classified as privately accessible charging. Examples of charging business models for bus electrification, which tend to be reliant on depots, are available in the e-bus case studies of the Global Electric Vehicle Outlook 2020 (Shenzhen and Santiago, for example).

Source: IEA analysis based on GSMP (2021), Policies for a mature, flourishing & equitable EV charging ecosystem,;WBCSD (2021), Value framework for sustainable charging infrastructure; Wappelhorst, S. et. al. (2020), Analysing policies to grow the electric vehicle market in European cities; and WFW (2020), The future of e-charging infrastructure: France.

Public charging infrastructure can be publicly or privately owned. If policy makers wish to use public land for charging infrastructure installation, they will need to consider various station ownership models, ranging from the owner-operator model to leasing arrangements. In an owner-operator model, the property owner covers all costs of the charger installation and operation and retains all revenues. In an external operator model, a third party, who shares part of the risk and revenues with the property owner, handles the operation of the charging station. In a lease model, the property owner's involvement is minimal as they only rent the space. The concession model resembles a lease arrangement, but the property owner is responsible for ensuring the necessary groundworks and electrical connections at the site, which allows them to retain ownership of the connection point. The choice of model determines the level of risk, but also of revenue and investment, assumed by the property owner. GSMP analysis has shown that the commercial viability of these various business models depends on the location of the charging infrastructure. The accompanying table provides the results of their suitability analysis for road-side, enroute and destination charging.

Several types of service providers have emerged in the EVSE ecosystem: Charge point operators (CPOs) provide the infrastructure and take care of the maintenance. E-mobility Service Providers (eMSP) provide charging services but do not operate the stations – their core business is developing charging networks and ensuring interoperability. Another category includes companies that provide turnkey charging as a service. Depending on the company, the property owner at a turnkey site may be required to furnish the necessary groundworks for the station, but maintenance and operation is managed by a third party.

Another charging business model relies on mobile applications or websites to facilitate so-called community charging. These social platforms make it possible for private (home) owners to share their charging point with other drivers, for a fee.

Lastly, battery-swapping has become increasingly popular for two- and three-wheeled vehicles. It is especially interesting for commercial two- and three-wheeled vehicles that travel long daily distances and have short break times. Under this model, station operators develop the entire swap system, including the battery and the vehicle – either alone or in collaboration with the original EV manufacturers.

Depending on the swap operator, batteries can be swapped out at designated stations or dropped off and picked up later. They can also be charged at home. The advantage to this approach is that charging can be very quick, the battery can be scaled and swapped according to user needs, and the cost of acquisition of the vehicle is reduced for the driver who no longer needs to own a battery. Furthermore, battery swapping can be deployed in locations that are convenient to the users, without the constraint of a grid connection (at the expense of having to transfer batteries from the swap stations to re-charging stations). Lastly, in tropical climates, centralised battery charging enhances safety. In many countries, Battery as a service models are encouraged for two- and three-wheelers. For LDVs, early experiments with battery swapping (Better Place and Tesla, for example) have not been particularly successful and the business model remains small on an international scale. This is due to manufacturers' reluctance to standardise their batteries, which are the highest value component of an EV. Battery swapping also requires very high upfront investment for the station and batteries, which means high rates of EV adoption are needed to justify the business case. There are also operational challenges in ensuring that users can always obtain a charged battery when they need one, as well as questions related to the legal liability of the different actors (OEM, battery swap operator, driver) in the event of an accident. Swapping stations are also resource intensive: Operators need to maintain a large fleet of batteries to serve drivers at different locations. That said, it is catching on in places like China, where several companies have launched battery-swapping businesses. The Chinese Ministry of Industry and Information Technology has even announced a pilot programme for swapping batteries in LDVs and buses. Alongside the benefits to EV users, battery swapping decouples charging from driving patterns which has the potential to reduce the burden on power networks and minimise generation curtailment.

There is no "one size fits all" solution for rolling out EV charging infrastructure

The full range of available options needs to be supported in a balanced portfolio which can cater to different user groups and vehicle types and provide EV drivers and grid operators maximum flexibility. One model may be better in certain circumstances than another, which is why there is no single solution for all. Policy makers should tailor their strategies to fit the local setting, planning approaches and the needs of their users.

The right EV charging solution will depend on several parameters, which should be incorporated into planning strategies. We will describe eight of these parameters here and discuss and how they can influence decision making.[2]

- **Living arrangements** in the community will determine the availability of home charging and thereby define any additional charging needs: The number of apartment buildings, for example, as well as the quantity of private parking spaces, and the density of accommodation are all important indicators. A higher proportion of multi-unit-dwellings correlates with a greater need to develop public charging infrastructure, as has been seen in the Netherlands. Strategies should take into account the global trend toward increased urbanisation, which is especially important in Africa and Asia. Data on the relative sizes of urban versus rural populations, as well as population density will give an indication on charging infrastructure needs and the availability of public parking spots. This could help guide policymakers in choosing between road-side slow chargers versus fast charging hubs in cities, for example.
- **Country and city structures and demographics**, as well as **principal travel routes**, need to be analysed. Enroute charging will be more pertinent in countries that have decentralised populations, where people frequently need to drive longer distances. For those with more centralised populations, roadside and destination charging may be more suitable. Densely populated countries often have a higher density of highway networks, which can make fast charging enroute an attractive solution. While sub-Saharan Africa is urbanising rapidly, the majority of the population still lives in rural areas, which impacts travel distances. This may also result in slower EV adoption rates, as examples from more mature EV markets show. One of the main barriers to EV adoption in Thailand, for example, is the long distances between major cities, which means drivers do not always have confidence they can complete their journey with an electric vehicle. In many cases, planning of additional enroute charging infrastructure should be combined with measures to promote intra-city public transport.
- Deployment of EV charging infrastructure should be integrated into **urban planning strategies and all national transportation policies**. EVs are crucial

[2] The order of appearance is not a classification of importance.

for the decarbonisation of road transport, but they need to be deployed in parallel with measures encouraging a shift toward the use of low-carbon (shared and non-motorised) transportation. In the Net Zero Scenario, the decarbonisation of transport assumes the adoption of policies that promote modal shifts. Planning the roll-out of charging infrastructure together with measures encouraging the shift towards urban public transit and long-distance buses and trains will help optimise the amounts of investment in EVSE that are needed and will help reduce the need for enroute charging infrastructure. At the local level, the deployment of charging infrastructure needs to be aligned with urban planning goals, including efforts to reduce car traffic in cities and increase investment in electrified public transport.

- The **location and geographic characteristics of the jurisdiction** – its vulnerability to climate change, for example, whether it is an island or on the mainland, its average ambient temperature, the mix and availability of renewable electricity – are all points to consider. Indeed, very warm or very cold climates have a negative impact on the efficiency of battery charging and battery lifetime. Furthermore, charging needs increase when a vehicle's interior heating or cooling systems are activated. Island countries may have different challenges with respect to grid integration issues and distances travelled. Meanwhile, the renewable electricity portfolio of a jurisdiction will also influence the choice of low-carbon charging solutions. In the Caribbean islands for example, range anxiety is less of an issue due to lower distances travelled, and EV smart charging and their use as storage (for grid flexibility applications) has a high potential for the integration of variable renewables and the mitigation of damage to the grid resulting from natural disasters.
- Understanding the **profiles of early EV adopters** will help policy makers to better understand their needs and which type of infrastructure to target and deploy first. In the Chinese city of Shenzhen, for example, the first electric delivery vehicles to be introduced were recharged overnight at depots. But once fast charging infrastructure became available near logistics centres (thanks to municipal subsidies), charging behaviour switched: Drivers preferred to charge their vehicles before the start of their shifts or during mid-day breaks. Latin America, the region with the highest per capita use of buses globally, sees strong growth in bus electrification. Governments have developed public-private partnerships to finance the fleet and infrastructure needs.
- **Vehicle type and use** also has a major influence on charging infrastructure needs. Europe has a high proportion of private LDVs which spend an average of 1 to 2 hours per day on the road. But in other economies, the dominant vehicle types differ. In sub-Saharan Africa, for example, most journeys are made by motorcycle taxi or minibus, which involve longer drive times and more kilometres travelled. India adapted its EVSE roll-out strategy to favour solutions for two-wheelers by developing a low-cost, slow AC charging standard. The existence of public transport, and its electrification, will also play a role in mobility habits and will help policy makers to prioritise their electrification efforts, as seen from the example of bus electrification in Latin American cities. At international workshops

organised recently by the GSMP, the heterogeneity of the many EV user groups being given priority was clear: In India, two-wheelers were at the top of the list, while in the United States, preference was given to ride-hailing companies. In Europe and South Africa, it was private commuters. Meanwhile, the respective market shares of Plug-in Hybrid Electric Vehicles (PHEV) versus Battery Electric Vehicles (BEV) in the EV also has an important influence on the demand for charging infrastructure. PHEVs, which have an internal combustion engine, can drive for longer distances with less dependence on public charging infrastructure. Nonetheless, expanding access to EVSE also encourages PHEV users to increase their mileage driven on electricity – substantially improving their contributions to emissions reduction and bolstering decarbonisation efforts.

- The **availability of grid capacity and connection** to charging stations is crucial and affects the deployment of EVSE, its location, and the type and number of charging points that can be installed. (In Northern Ireland, for example, deployment has been hampered by grid capacity issues.) Grid capacity determines the maximum power of the installable chargers, as well as the cost and lead time – since any grid upgrades will increase both. A station may function off-grid, with its own generation source (A solar PV array with battery storage as is done in Barbados, for example), or as a battery-swapping station with off-site recharging. Off-grid solutions are essential in places where the grid is less reliable or access to electricity is not widespread, such as in sub-Saharan Africa. Furthermore, the deployment of charging infrastructure should be considered together with the decarbonisation of the electricity mix, to maximise the full decarbonisation potential from EVs.
- Finally, it is important to consider the **stage of EV deployment** in the jurisdiction. Some solutions may be appropriate at earlier stages of electric vehicle adoption but are not necessary anymore in more mature markets. Indeed, the maturity of the EV market directly influences the profitability of charging infrastructure: Jurisdictions where EV market penetration is low often face a utilisation gap, which usually requires policy intervention to overcome. In Europe, it is estimated that once BEVs reach 7.5% of the total vehicle fleet, mandatory targets for private or public infrastructure are no longer needed. At least one study suggests that once a critical density of charging networks is reached, it is possible to achieve increasing returns to scale – in other words, as more drivers adopt EVs, the number of charging stations needed per EV could actually decrease.

By considering their unique characteristics of their jurisdictions, policy makers can design charging infrastructure roll-out programmes that target the needs of local drivers and constituents. We have identified two types of approaches: those that are planning-based and those that are demand-driven. In a planning-based approach, the jurisdiction selects targeted locations for charging stations which meet a need (for example, next to strategic infrastructure). In a demand-driven approach, as in Amsterdam for example, installation decisions are made in response to driver requests, pointing out a gap. This request is then reviewed by the city which designates the exact location, guided by maps provided by the stakeholders. Demand-driven charge points may be favoured in markets where EV penetration is still low, because they tend to have better utilisation rates. However, a minimum amount of coverage is required to overcome range anxiety and allow for inclusive access to charging. As the market matures and EV adoption becomes more widespread, a balancing of these two approaches is recommended. In the example of the Netherlands, a planned deployment of 1,000 chargers was adopted in the initial stages, followed by demand-driven strategies. More recently, Dutch municipalities have returned to planning-based approaches to tailor the solutions to meet projected EV growth. Where policy makers do not wish to intervene at all, they can also follow a market-based approach and leave location decisions to investors, who will aim to find the best business models for publicly available chargers.

Commercial viability can be a challenge at first – but proper planning can help lower some start-up costs

The deployment of public EV charging infrastructure requires significant up-front investments and – in the early years, at least – can be slow to turn a profit. While hard to avoid an initial utilisation gap – where demand for charging infrastructure falls short of the required coverage – it can be partly mitigated through simple and efficient processes for approving EVSE siting and installation. Addressing so-called "soft costs" for EV service providers – the permitting processes, the communication with stakeholders, the connection to the grid, etc. – is one area where the start-up burden can be significantly reduced. Being cognizant of investors' soft costs at the policy drafting stage allows them to focus on managing budgets for the infrastructure itself. Recognising this, the government of India provided land for charging infrastructure free of cost, through a revenue sharing model. Rwanda took a similar approach.

One major source of delays to EVSE installation is the approval and permitting process. In some jurisdictions, this can last many months, either because the authorities lack dedicated personnel or they do not prioritise it. In some instances, the permitting process includes a requirement (often lengthy) public hearings. This was the case in the U.S. state of California, for example – until the state streamlined permitting procedures for EV charging and even created a permitting guidebook for charge-point installers. Where it is possible to harmonise these processes at a national level, transparency could be improved, and administrative costs could be significantly reduced.

On a related note, communication with stakeholders can be challenging for new entrants to the EV charging market, especially if there is no designated point of contact – or if the process requires operators to negotiate with several different authorities. Among the main pieces of information needed to plan an EVSE installation are grid capacity and connection possibilities. Utilities need to be involved and transparent with EVSE installers and governments on the possibilities and costs at potential locations, to facilitate planning and efficient connection of the station to the grid. Even when grid infrastructure is already in place, it can take anywhere from three months to three years to obtain a grid connection. Clear guidelines about the requirements for charging infrastructure construction, the points of contact, as well as the disclosure of hosting capacity are key elements to decreasing procedural time and costs.

The electricity rates assessed to the charge point operator are another point to consider, since this can strongly affect business models and revenues. These rates vary significantly around the world. Not every country has EVSE-tailored electricity tariffs and rate structures also vary widely. In countries like the United States and South Korea, for example, utilities include a fee that is linked to a station's capacity (which is calculated based on the peak demand in a given time period). In the early stages of EV adoption, the rates fast charging stations can often exceed revenues: One analysis in the U.S. state of Colorado found that, under typical utility tariffs, fast charging stations only became profitable once utilisation rates reached 30%. Policy makers should be aware of this issue and work with utilities to find solutions to support EVSE operations in the early stages.

Recommendations

International experience has shown that policy makers at every level have a role to play in the roll-out of public charging infrastructure: supranational bodies for cross-country corridors such as the EU Trans-European Transport Network; national bodies like Costa Rica's network of fast chargers or Iceland's ring road; and regional and local authorities to handle coverage beyond highways and large metropolitan centres. Their intervention is crucial for the deployment of charging infrastructure – especially since initial utilisation rates will be insufficient to drive the installation of sufficient infrastructure to mitigate range anxiety.

Sample measures to facilitate charging infrastructure roll-out

Tool/Measure	Example
Communication and designation of contact persons or institutions	**India** designated the national Bureau of Energy Efficiency as the primary agency responsible for the roll-out of public EVSE and developed a handbook to guide policy makers and authorities. This handbook also lists the state agencies in charge of EVSE infrastructure and deployment. **Portugal** set up a network management body (state-owned company MOBI.E) to deploy public charging infrastructure and ensure inter-operability and scalability. **The Netherlands** created a public-private platform to research, implement and inform about EVSE policies
Mandates and regulations	**Korea**'s Smart Energy Strategy: The government wants to ensure open access to all charging stations with a single membership card. **Peru'**s Decreto Supremo 022-2020-EM defines charging infrastructure and mandates interoperability of stations. In **India**, 20% of residential and commercial buildings' parking spaces are reserved for EVSE. In selected cities, there must be one charging station every 3 km; On both sides of every highway, there must be one charge point every 25km. **Indonesia**'s regulation 13/2020 details requirements for EV charging stations and battery swap stations.
Financing – through incentives, subsidies, or direct investment	**China** supports local governments with financial assistance for EVSE roll-out if they have met their EV adoption targets. **Chile**'s "Mi Taxi Eléctrico" programme subsidises taxi companies that switch from ICE to EV and provides financial assistance for a home charger. **Indonesia** offers tax breaks for the deployment of public charging infrastructure**.** **Rwanda** exempts charging infrastructure equipment (as well as EVs and batteries) from import duties and value-added taxes**.**

Tool/Measure	Example
Land ownership	The city of Stockholm, in **Sweden**, awarded land free of charge to utilities to set up « charging streets » with many charging points. **India** made public land available to companies to build charge points in exchange for a share of the revenues.
Tenders	**France** organised a public tender for the right to use government land for the purpose of installing and operating EVSE. Similarly, **Switzerland** held a tender for the right to build fast charging infrastructure in batches of locations (high-traffic roads, rural roads, etc.)
Grid upgrades and extensions	In **France**, a portion of public EVSE connection costs may be assumed by the grid operator. **California's** Public Utilities Commission mandates that utilities provide "utility-side make-ready" infrastructure to support EV charging. **India** has established maximum grid connection times.

Note: This table presents a non-exhaustive list of examples of policy measures.

Source: IEA analysis based on NITI Aayog (2021), Handbook of electric vehicle charging infrastructure implementation; Energy Cities (2016), MOBI.E – E-Mobility Network; NAL (2022), Nationale Agenda Laadinfrastructuur; Maeng, K. et.al. (2020), How much electricity sharing will electric vehicle owners allow from their battery? Incorporating Vehicle-to grid technology and electricity generation mix; El Peruano (2020), Decreto Supremo Numéro 022-2020-EM; Singh, S. (2019), Buildings will have to allot 20% parking space for EV charging; Singh, S. (2022), Govt land to private agencies for setting up EV public charging stations through bidding; MEMR Indonesia (2020), Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 13 Tahun 2020; Mahalana, A. et.al. (2021), Indonesia transport electrification strategy; Ministerio de Energia, Chile (2021), Invitan a conductors de taxis y colectivos del Gran Velparaíso a sumarse a la Electromovilidad; German-Indonesian chamber of commerce (2022), Indonesia issues legal framework for electric vehicles; Republic of Rwanda, Ministry of Infrastructure (2021), Strategic paper on electric mobility adaptation in Rwanda; Wappelhorst, S. et.al. (2020), Analysing policies to grow the electric vehicle market in European cities; WFW (2020), The future of e-charging infrastructure: France; European Commission (2020), 2020 recommendations for recharging point tenders; Muller, M.et.al. (2021), CA approves new rules to support EV charging infrastructure; Government of India, Ministry of Power (2022), Charging infrastructure for EV – the revised consolidated guidelines and standards.

The country cases cited here represent just a few examples of policies designed to ensure the rapid deployment of charging infrastructure. EV adoption is still in its beginnings, and it is important that the resources invested are efficiently deployed. We therefore encourage policy makers to follow these five key recommendations:

Break institutional silos to enable cooperation at every level

Planning, installing and operating charging infrastructure for electric vehicles involves many different stakeholders of different backgrounds. Cooperation between these various actors is key to ensuring a smooth network roll-out. This means that institutions and ministries from different domains need to actively engage with one another, exchanging points of view and identifying challenges, to ensure that no aspect is overlooked.

In many cases, private and public infrastructure are managed by different entities and are governed by different laws. Nonetheless, given that the amount of private charging available has a direct impact on the amount of public charging that is needed, these should be planned in concert. Typically, public charging infrastructure is managed either by transport or energy institutions. But when it comes to planning new charging infrastructure, this should be done in coordination with all relevant entities, including transport and energy departments, urban planning units as well as with utilities, to ensure the best way forward.

To that end, we recommend that institutions adapt their structures to break down outdated organisational silos and facilitate cross-sectoral discussion on EV charging infrastructure. We recognise that wholesale reform of institutions can be a complex and time-consuming process – which is why we recommend creating cross-sectoral working groups instead. The U.S. government, for example, created a joint office of the departments of energy and transportation responsible for managing the expansion of public charging infrastructure. We also advocate regular dialogue between different levels of public administration – national, regional and local – to ensure that their policies are coherent. Policy makers should also be encouraged to share ideas and experiences with their counterparts from other cities, countries or regions.

By re-thinking and reforming organisational structures, new opportunities are created: to develop integrated strategies for the deployment of electric vehicles and EV charging infrastructure; to designate contact points for the processes related to EVSE installation; and to provide staff with the means to build their expertise.

Tailor your strategy to your jurisdiction and target the low-hanging fruit

As mentioned previously, every country, region or city is unique and will have to adapt to their own priorities and parameters. Collect the relevant data – vehicle stock, ownership rates and profiles, average kilometres travelled, modes of travel, access to home charging, population density, parking availability, etc. – to ensure you have a clear picture of the situation in your community.

Once that is done, the deployment steps should target the low-hanging fruit first: If there is a large commercial vehicle fleet, then building measures to support their electrification, like the "Mi Taxi Electrico" programme in Chile or the OLEV taxi scheme in the United Kingdom, is relevant. Electrifying fleets has proven to be a good opportunity for a rapid scale-up of EVs and their infrastructure. To lead by example and to create momentum for the deployment of EVs and EVSE, electrifying public and government fleets has potential. As an example, in Uruguay, the state utility has electrified part of its vehicle fleet and taken an integral role in the country's electrification drive. On the other hand, in places where private charging is expected to be predominant, investment should be targeted towards the installation of charging infrastructure in residential and commercial buildings.

Policy makers can also encourage the sharing of existing infrastructure – both private and semi-public – to allow for the most efficient use of existing charge points.

The list of possibilities is long – and not every option is budget-intensive. Planning allows governments to identify which areas or types of charging infrastructure require new investment to develop and which ones may only need supportive mandates or regulations.

Meanwhile, policies that encourage modal shifts towards shared public transport will lead to fewer electric passenger cars on the road – and thus less demand for charging infrastructure. An optimal roll-out strategy needs to consider the impacts of different transportation policy objectives on one another and integrate them accordingly.

Make EVs a political priority to attract infrastructure investment

Deploying public charging infrastructure requires a considerable amount of investment, which cannot always be shouldered by public institutions alone. Experience from more mature EV markets shows that, with the right set of incentives, private investors are quite willing to share the costs of charging infrastructure development. And competition among prospective providers is reliable way of obtaining the best quality infrastructure at the lowest possible price.

Governments should first set clear targets for EV and EVSE deployment, which will demonstrate to private investors that the topic is high on the political agenda. They should also take steps to guarantee transparency in the tender process. Once an infrastructure concession is awarded, the procedures for obtaining the necessary licences and permits should be efficient, clear and barrier-free. (The Indian government, for example, sets clear targets for the maximum delay allowed for the connection to the electric grid.) Facilitating communication between stakeholders by designating contact people within the relevant institutions – as India has done with its EVSE implementation handbook – and easing the access to grid capacity and interconnection data will help build market trust and participation.

Lastly, to ensure business models are as viable as possible, policy makers should consider the impact of electricity rates as detailed above, and work with utilities to minimise this cost for EVSE operators. For tender processes, attributing contracts for longer durations (15 years) is also a good idea to maximise charge point operators' chances of turning a profit.

Encourage standardisation to improve user experience and efficient deployment of infrastructure

The user experience is crucial in the electrification of transport. Because infrastructure concessions are susceptible to "lock-in effects" – where switching to an alternate supplier is difficult without incurring significant costs – policy makers need to be confident that users will have access to charging infrastructure that is reliable, operational and adapted to their needs. Smart technology has made it possible to closely monitor service quality at charge points. From the user perspective, transparency and quality-related data availability is critical: Drivers need to know which charging stations are working and available; whether there is a waiting time (and how long); the charging speed and price; as well as the available payment methods. To ensure the quality of the service and the effectiveness of the public money invested, policy makers can set performance targets with the vendor and establish mandatory maintenance schedules. Tenders initiated by public authorities can similarly integrate quality, operation and maintenance requirements and grade bids accordingly, such as was done by the German Federal Ministry of Transport and Digital Infrastructure.

Meanwhile, to ensure accessibility to the broadest possible range of users, charging stations should be designed to cater to all types of plugs (CHAdeMO and CCS for fast charging, for example) and plug-in positions (front, rear, side – which can vary between EV models and type). That said, if governments can work with the industry to standardise these, the costs for charging infrastructure installation could be reduced significantly.

Standardisation and interoperability are key aspects to consider. Selecting codes and standards at government level increases consumer trust in the viability of installations and reduces the risk of being locked into an obsolete infrastructure. Policy makers should investigate both the connection from the EV to the EVSE, and the EVSE to the grid. Charging standards (such as those set by the International Electrotechnical Commission), equipment certification, cybersecurity and installation codes need to be reviewed and adapted for EVSE.[3] For the communication between charging station and the charge management system, open standards such as the Open Charge Point Protocol (OCPP) allow for more transparency and flexibility (since station hosts can easily switch to a different network if there is an issue with their primary network) as well as more streamlined software requirements.

[3] For further details we invite the reader to refer to this publication from NREL, available online: Building Blocks of Electric Vehicle Deployment: A Guide for Developing Countries (nrel.gov)

Competition between charging networks is seen as beneficial for pricing and quality. Without interoperability protocols in place, however, multiple networks can end up being a hassle for users: Drivers may have to subscribe to several charging providers, for which they must create separate accounts and passwords. That is why we recommend that all charge points have roaming capability. Roaming allows charging service providers to cooperate with others to create a roaming network and offer charging to all customers within that network. While offering ad-hoc payment is a good start for broadening access, roaming has the added advantage of providing data insights that can enable a tailored fee system, for example, or smart charging. An example of a strong common platform for charging exists from the State Grid Corporation in China, where 1 million registered users have access to a network of 300 000 charge points. Another example is Portugal, where all publicly accessible charging stations are connected to the same roaming system, through which users are able to access any charge point in the country – regardless of the station's operator – through a single subscription.

Create incentives and plan for the infrastructure of tomorrow

Every charge point installed today will be there for years to come, so it needs to be future proof. This means that planners need to anticipate future challenges when they set EV stock targets and develop strategies for electrifying transportation and promoting modal shifts. Smart data, as well as smart charging, are two key ways to ensure that today's chargers continue to support the smooth integration of EVs.

Connecting charging stations and equipping them with smart metering benefits both the operator (who can track utilisation and maintenance needs) and the user (who can find charge points and get information on availability, pricing and charging speeds). It is also useful for research and planning future rollouts. The data collected will yield valuable insights on charging habits, energy use, peak power needs, effectiveness of pricing schemes, etc. At the moment, there are few incentives for station operators to share their data – in fact, many stations lack independent sub-metering, which prevents accurate monitoring of individual charging behaviour. Policy makers need to ensure that charging data is available for research and modelling purposes, while also making sure the privacy of individual drivers is protected. Local governments in the Netherlands,and India have appealed to charge point operators and service providers to provide usage data for monitoring purposes.

It is also crucial that EVs be charged with low-carbon electricity to reduce their impact on the grid and to transform EVs from a threat to sustainable growth into an asset. Electric vehicles could account for as much as 4% of global annual electricity demand by 2030, and their share of peak power demand could rise to between 4% and 10%. Locally, peak loads from EV charging could increase by up to 86% in multi-unit dwellings, and by 90% in highway corridors where fast chargers are installed. To anticipate the needs of future EV fleets and minimise the impact of charging infrastructure on the grid, policy makers should work with utilities to promote the use of time-of-use tariffs that encourage charging at off-peak times. Pricing should be set to reward users who charge at times when low-carbon electricity is plentiful – during the daytime, say, for countries with high solar PV availability. Investments in smart charging infrastructure should also be encouraged. Smart technology makes it possible for utilities to signal to users when electricity supplies are ample (and therefore cheaper) and provides flexibility to the grid. Installing connected chargers now also eliminates the risk of becoming locked into an infrastructure without this capability – resulting in load management issues and expensive grid upgrades in the future.

It is wise to take a forward-looking approach when investing in new infrastructure. Planning ahead now helps to reduce costs later when the time comes to expand the charging network. The cost of digging trenches to connect charge points to the grid, for example, is often significant – but it can be even more expensive down the road if lines need to be dug up for upgrades down the road. Having a clear view of future charging needs makes it possible to plan scalable infrastructure from the beginning.

Finally, the deployment of electric vehicle charging infrastructure should align with the broader mobility targets in your jurisdiction and with ongoing efforts to encourage the transition to low-carbon and zero-emission transport modes (including walking and cycling) – especially in urban centres.

Conclusion

Accelerating the adoption and widespread use of electric vehicles is essential for decarbonising economies worldwide. But successful EV deployment requires the installation of charging infrastructure at a more rapid pace. This is where policy makers have an important role to play. The measures and recommendations presented here represent a significant opportunity to enact measurable change.

The International Energy Agency, under the auspices of the Global Environment Facility's global E-mobility programme, will continue to support countries in their shift to electrified transport. A series of reports and tools will be produced to give further information on the role of governments in supporting charging infrastructure and safely integrating EVs into the grid.

Annex

Abbreviations and acronyms

AC	Alternating Current
BEV	Battery electric vehicle
CPO	Charge point operator
CCS	Combined charging system
CHAdeMO	Charge de move
eMSP	E-mobility service provider
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
GEF	Global Environment Facility
GSMP	Global Sustainable Mobility Partnership
HDV	Heavy-duty vehicle
ICE	Internal combustion engine
LDV	Light-duty vehicle
OCPP	Open charge point protocol
OEM	Original Equipment Manufacturer
OLEV	Office for Low Emission Vehicles
PHEV	Plug-in hybrid electric vehicle
PV	Photovoltaic

Glossary

km	kilometre
kW	kilowatt
kWh	kilowatt hour

IEA Publications

International Energy Agency

Website: www.iea.org

Contact information: www.iea.org/about/contact

Typeset in France by IEA – April 2022

Cover design: IEA

Photo credits: © ShutterStock