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Accelerating the Global Clean Energy Transition

Electric Vehicles Initiative

# Global EV Outlook 2017

## Two million and counting

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# Acknowledgements

This publication was prepared by the Energy Technology Policy division of the Directorate of Sustainability, Technology and Outlooks (STO) of the International Energy Agency (IEA), under the direction of Kamel Ben Naceur and the guidance of Jean-François Gagné. Pierpaolo Cazzola led this activity as EVI Co-ordinator.



The report was jointly developed by Pierpaolo Cazzola and Marine Gorner with the contribution of Luis Munuera (for the section on challenges and opportunities for the power sector) and the support of Renske Schuitmaker and Erik Maroney. Marine Gorner also co-ordinated the data collection and carried out the development of the IEA datasets underlying this analysis.

The following individuals contribute to developing the activities of the Electric Vehicles Initiative (EVI) on behalf of their member governments, including the provision of data and assistance (including review) in the preparation of this report: Carol Burelle (Canada), Pei Li (the People's Republic of China [hereafter "China"]), Lijin Zhao (China), Yong Jin (China), Chengxi Li (China), Guofang Liu (China), Cédric Messier (France), Daniel Strat (France), Maude Premillieu (France), Vincent Delporte (France), Gereon Meyer (Germany), Birgit Hofmann (Germany), Jiro Arai (Japan), Zuiou Ashihara (Japan), Kaori Higashitani (Japan), Sonja Munnix (the Netherlands), Marten Hamelink (the Netherlands), Rik Boddeus (the Netherlands), Jannis Rippis (Norway), Asbjørn Johnsen (Norway), Havard Grothe Lien (Norway), Andreas Enge (Norway), Martin Palm (Sweden), Peter Kasche (Sweden), Tim Ward (United Kingdom), Alex Philpott (United Kingdom), Bob Moran (United Kingdom), Daniel Noll (United States), David Howell (United States), Anand Gopal (United States) , Alex Schroeder (United States), Jake Ward (United States), Cabell Hodge (United States), Matteo Muratori (United States), Rudy Kahsar (United States).

Pravin Agrawal (India), Vishvajit Sahay (India), Raj Kumar Singh (India), Hwanjung Jung (Korea), Ki-Yeol Kim (Korea), Hyun Park (Korea) also supported the data collection.

Ock Taeck Lim (Ulsan University, Korea), Jian Liu (Energy Research Institute [ERI], China), Zhong Lyu (IEA), Michael Rask (IEA Technology Collaboration Programme on Hybrid and Electric Vehicles [IEA HEV TCP] representative for Denmark), Sandra Retzer (GIZ [Deutsche Gesellschaft für Internationale Zusammenarbeit] China), Xinnan Wang (GIZ China) and Bert Witkamp (AVERE [the European Association for Battery, Hybrid and Fuel Cell Electric Vehicles] and European Alternative Fuel Observatory) also provided data and assistance and contributed to the review.

External reviewers included Rosemary Albinson (independent reviewer), Marcello Contestabile (KAPSARC), Rob de Jong (United Nations Environment Programme [UNEP]), Anthony Eggert (ClimateWorks), Dale Hall (International Council on Clean Transportation [ICCT]), Jan Hentschel (Volkswagen), Cabell Hodge (National Renewable Energy Laboratory [NREL], United States), Yong Jin (Shanghai International Automobile City), Alexander Körner (independent consultant), Yossapong Laoonual (King Mongkut's University of Technology Thonburi [KMUTT], Thailand), Francisco Laveron Simavilla (Iberdrola), Nic Lutsey (ICCT), Maurizio Maggiore (European Commission), Josselin Mulsant (Tesla), Matteo Muratori (NREL), Wei-Shiuen Ng (International Transport Forum), Patrice Nogues (Electricité de France [EDF]) Todd Onderdonk (ExxonMobil), Alberto Piglia (ENEL), Breno José Pimentel Lyro (Petrobras), Michael Rask (IEA HEV TCP), Gen Saito (Nissan), Ichiro Sakai (Nissan), Mark Schipper (Energy Information Administration, United States), Takanori Shiina (Honda), Yuichiro Tanabe (Honda), Tali Trigg (GIZ), , Caroline Watson (C40), Harm Weken (FIER Automotive), Mark Wenzel (California Environmental Protection Agency [CalEPA]) and Markus Wråke (Energiforsk).

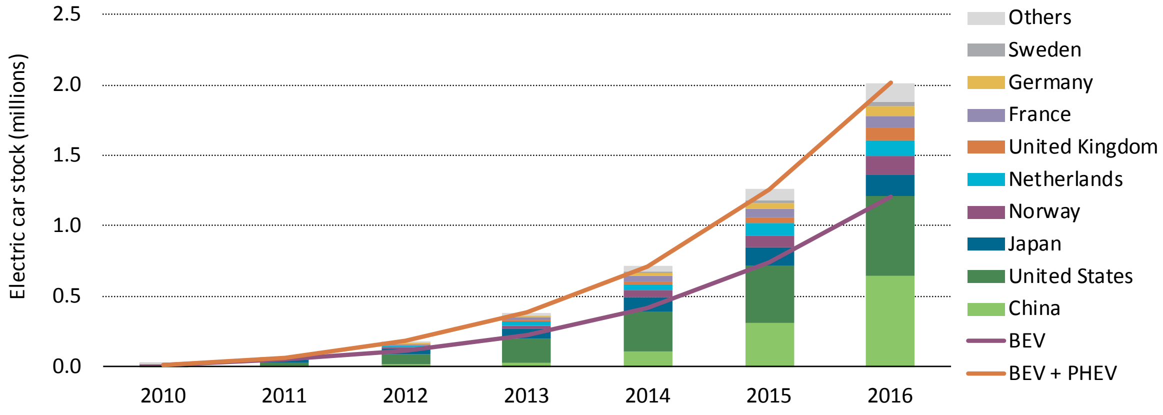
IEA reviewers included Kamel Ben Naceur, Simon Bennett, Laura Cozzi, Jean-Francois Gagné, Rebecca Gaghen, Paul Simons and Laszlo Varro. The report was edited by Adam Majoe.

# Executive summary

New registrations of electric cars[1] hit a new record in 2016, with over 750 thousand sales worldwide. With a 29% market share,[2] Norway has incontestably achieved the most successful deployment of electric cars in terms of market share, globally. It is followed by the Netherlands, with a 6.4% electric car market share, and Sweden with 3.4%. The People's Republic of China (hereafter, "China"), France and the United Kingdom all have electric car market shares close to 1.5%. In 2016, China was by far the largest electric car market, accounting for more than 40% of the electric cars sold in the world and more than double the amount sold in the United States.

The global electric car stock surpassed 2 million vehicles in 2016 after crossing the 1 million threshold in 2015 (Figure 1).

**Figure 1 • Evolution of the global electric car stock, 2010-16**




Notes: The electric car stock shown here is primarily estimated on the basis of cumulative sales since 2005. When available, stock numbers from official national statistics have been used, provided good consistency with sales evolutions.

Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2017a), IHS Polk (2016), MarkLines (2017), ACEA (2017a, 2017b) and EEA (2017).

**Key point:** The electric car stock has been growing since 2010 and surpassed the 2 million-vehicle threshold in 2016. So far, battery electric vehicle (BEV) uptake has been consistently ahead of the uptake of plug-in hybrid electric vehicles (PHEVs).

Until 2015, the United States accounted for the largest portion of the global electric car stock. In 2016, China became the country with the largest electric car stock, with about a third of the global total. With more than 200 million electric two-wheelers,[3] 3 to 4 million low-speed electric vehicles (LSEVs) and more than 300 thousand electric buses, China is also by far the global leader in the electrification of other transport modes.

As the number of electric cars on the road has continued to increase, private and publicly accessible charging infrastructure has also continued to grow. In 2016, the annual growth rate of publicly available charging (72%) was higher, but of a similar magnitude, than the electric car stock growth rate in the same year (60%).

[1] Electric cars include battery-electric, plug-in hybrid electric, and fuel cell electric passenger light-duty vehicles (PLDVs). They are commonly referred to as BEVs, PHEVs, and FCEVs in this report. Given their much wider diffusion, the scope of this report is limited to BEVs and PHEVs.

[2] Market share is defined, under the scope of this report, as the share of new registrations of electric cars in the total of all PLDVs

[3] In this report, the term "two-wheelers" refers to motorcycles and excludes bicycles.

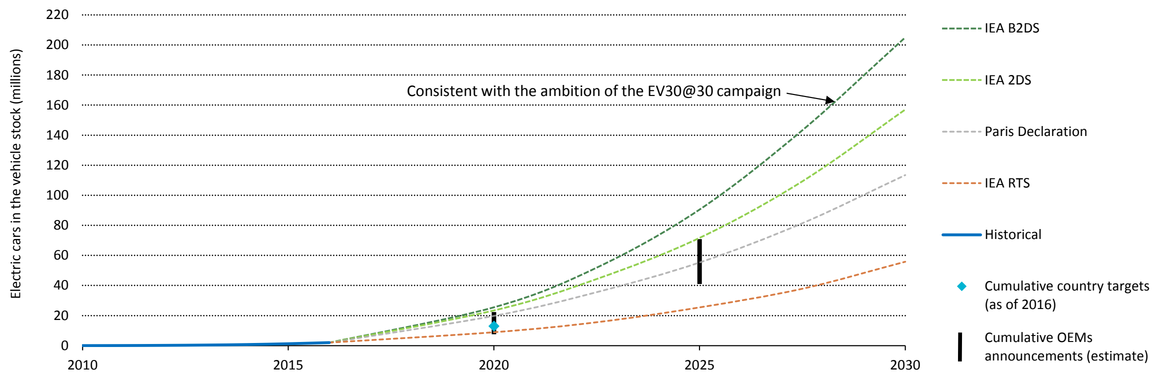
Despite a continuous and impressive increase in the electric car stock, electric vehicle supply equipment (EVSE) deployment and electric car sales in the past five years, annual growth rates have been declining. In 2016, the electric car stock growth was 60%, down from 77% in 2015 and 85% in 2014. The year 2016 was also the first time year-on-year electric car sales growth had fallen below 50% since 2010.



Declining year-on-year increments are consistent with a growing electric car market and stock size, but the scale achieved so far is still small: the global electric car stock currently corresponds to just 0.2% of the total number of passenger light-duty vehicles (PLDVs)[4] in circulation. Electric vehicles (EVs) still have a long way to go before reaching deployment scales capable of making a significant dent in the development of global oil demand and greenhouse gas (GHG) emissions.

Research, development and deployment (RD&D) and mass production prospects are leading to rapid battery cost declines and increases in energy density. Signs of continuous improvements from technologies currently being researched confirm that this trend will continue, narrowing the cost competitiveness gap between EVs and internal combustion engines (ICEs). Assessments of country targets, original equipment manufacturer (OEM) announcements and scenarios on electric car deployment seem to confirm these positive signals, indicating a good chance that the electric car stock will range between 9 million and 20 million by 2020 and between 40 million and 70 million by 2025 (Figure 2).

**Figure 2 • Deployment scenarios for the stock of electric cars to 2030**




Notes: The RTS incorporates technology improvements in energy efficiency and modal choices that support the achievement of policies that have been announced or are under consideration. The 2DS is consistent with a 50% probability of limiting the expected global average temperature increase to 2°C. The B2DS falls within the Paris Agreement range of ambition, corresponding to an average increase in the global temperature by 1.75°C.

Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2017a), IHS Polk (2016), MarkLines (2017), ACEA (2017a, 2017b) and EEA (2017). Country targets in 2020 reflect the estimations made in EVI (2016a) and updates in 2016. Sources listed in Table 2 have been used here to assess the magnitude of OEM announcements. The methodology used for this assessment is discussed in the main text. Projections on the stock deployed according to the Paris Declaration are based on UNFCCC (2015a). Projections on the EV uptake in IEA scenarios were developed using the IEA Mobility Model, March 2017 version (IEA, 2017a).

**Key point:** The level of ambition resulting from the OEM announcements assessed here shows a fairly good alignment with country targets to 2020. To 2025, the range estimated suggests that OEM ambitions lie within the range corresponding to the Reference Technology Scenario (RTS) and 2DS projections from the IEA, broadly matching the Paris Declaration on Electro-Mobility and Climate Change and Call to Action (Paris Declaration).

[4] PLDVs include passenger cars and passenger light trucks but exclude two-wheelers, three-wheelers, and low-speed/low-power four-wheeled vehicles. The classification used here attempts to match, to the extent possible, the "Category 1-1 vehicle" defined in UNECE (2005) and its following amendments, and, in countries where this regulation applies, "Category $M_1$" defined in UNECE (2016).

Despite this positive outlook, it is undeniable that the current electric car market uptake is largely influenced by the policy environment. Key support mechanisms currently adopted in leading electric car markets target both the deployment of electric cars and charging infrastructure:

- EV support typically takes the form of RD&D on innovative technologies, mandates and regulations, financial incentives and other instruments (primarily enforced in cities) that increase the value proposition of driving electric. Public procurement[5] (leading by example) is also well suited to facilitating early EV uptake.
- EVSE deployment is supported by the development of standards ensuring interoperability, financial incentives, regulations (including building codes) and permits.



A number of cities have been at the forefront of stimulating EV deployment, whether in the two-wheeler, PLDV or bus segments, and municipalities are important players in helping accelerate the transition to electric driving. By testing and demonstrating best-practice EV and EVSE support policies, cities can not only act as models for other cities that seek to accelerate their transition to electric driving but also provide an example for a wide application of best practices (e.g. at the national or global level), helping to improve the cost efficiency of the policy development process. The demand-based approach adopted by the metropolitan area of Amsterdam to deploy its EVSE network by providing publicly accessible chargers to electric car owners who request them, under certain conditions, is one of the most interesting examples in this respect.

Urban areas are also excellent platforms for the experimentation of novel passenger and freight transport services based on vehicle and ride-sharing concepts or autonomous driving capabilities. Given the high mileage of shared vehicles, these concepts have strong synergies with transport electrification.

Policy support will remain indispensable at least in the medium term for lowering barriers to electric car adoption. As electric car sales keep growing, governments will need to reconsider their policy tools. Even if differentiated taxes based on environmental performance, fuel economy regulations and local measures (such as differentiated access to urban areas) are likely to remain important, the need for vehicle purchase incentives will diminish, and subsidies for electric cars will not be economically sustainable with large sales volumes. Revenues collected from conventional fuel taxes will also shrink, requiring a transition in the way revenues aiming to develop the road transport infrastructure are collected.

EV charging could also have a sizeable impact on the loads applied to the grid at certain times and locations, with consequences for adequacy and quality of power supply, the risk of cost increases for consumers and negative feedback on transport electrification prospects. EVSE deployment needs to be conceived in a way that handles these risks and takes advantage of the options available for mitigating these impacts. Large-scale electric car charging and demand response will require the joint optimisation of the timing and duration of recharging events, the modulation of power delivered by charging outlets (defining the speed of charge) and may involve a reliance on vehicle-to-grid solutions. For fast chargers, managing power demand is also likely to require the deployment and use of stationary storage at the local or grid level.

[5] Public procurement refers to the procurement of vehicles by the public sector at the national, state, regional or municipal levels. These include government fleets as well as electric buses and dedicated fleets, such as police fleets or garbage trucks.

# Introduction and scope

## Introduction

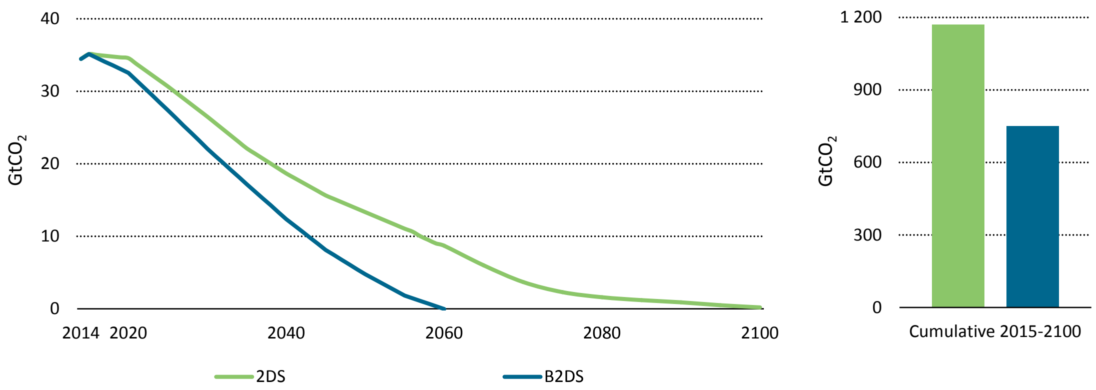


Announced in December 2015 and enforced in November 2016, the Paris Agreement set the objective of limiting the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels (UNFCCC, 2015b). Figure 3 illustrates the GHG emissions reductions that could be compatible with this target by looking at two carbon budgets that reflect two possible IEA scenarios (IEA, 2017b):

- 1 170 $GtCO_2$ of cumulative emissions for the 2015-2100 period, as in the IEA Two Degree Scenario (2DS), providing a 50% chance of limiting average future temperatures increases to 2°C
- 750 Gt $CO_2$ of cumulative emissions for the 2015-2100 period, as in the Beyond Two Degree Scenario (B2DS), coupled with a 50% chance of limiting average future temperatures increases to 1.75°C.

In both cases represented in Figure 3, energy-related GHG emissions will need to reach net-zero in the second half of this century: close to 2060 for the B2DS and close to 2090 for the 2DS. The transport sector, which currently accounts for 23% of global energy-related GHG emissions, will need to deliver major emissions cuts for countries to achieve their goals.

**Figure 3 • GHG emission budgets and emission trajectories to 2100 for the energy sector, 2DS and B2DS**




Source: IEA (2017b).

**Key point:** Without net negative emissions, energy sector $CO_2$ emissions need to fall to zero in the second half of the century to meet the ambition of the Paris Agreement.

The electrification of transport plays a large role in all IEA scenarios aiming to achieve the decarbonisation of the energy system, where increasing transport electrification goes hand-in-hand with decarbonising the electricity sector (IEA, 2017b).[6] Electrification will be crucial in short-distance vehicles such as two- and three-wheelers and PLDVs, as well as public transport and freight delivery vehicles used in urban environments. In the 2DS, the plug-in PLDV stock exceeds

[6] Other relevant solutions capable of contributing to several sustainability goals for the transport sector are articulated under the "avoid, shift and improve" strategy (IEA, 2017b). They include: reducing travel distances (e.g. through compact city development and the application of integrated urban and transport planning and the optimisation of road freight deliveries) (avoid); increasing the share of public transport modes in urban passenger transport and shifting road freight activity to rail and shipping (shift); and accelerating the deployment of energy efficiency for all vehicles, increasing the share of zero-emission vehicles (including FCEVs) and promoting the use of low-carbon fuels (improve).

150 million units (10% of the total) by 2030. By 2060, the 2DS projects that 1.2 billion electric cars, representing more than 60% of the total PLDV stock, will be in circulation. In the same scenario, the stock of electric two-wheelers is projected to exceed 400 million in 2030 (around 40% of the global total), and two-wheelers become fully electrified by 2055 (IEA, 2017b). Under the B2DS, transport electrification happens at an even faster pace: electric cars represent 85% of the total PLDV stock by 2060, and two-wheelers are fully electrified by 2045.



With zero tailpipe emissions in the case of full-electric driving vehicles, EVs also offer a clean alternative to vehicles with ICEs by helping to reduce exposure to air pollution resulting from fuel combustion and limiting noise. This is especially relevant in urban areas and along major transportation axes.[7] The relevance of EVs for the reduction of air pollution and noise is well demonstrated by the leading role that cities assume in promoting EV deployment: in 2015, nearly a third of global electric car sales took place in just 14 cities (Hall et. al, 2017). Major global urban centres also tend to witness higher electric car market penetration compared to their country averages (Figure 16).

## The EVI

The Electric Vehicles Initiative (EVI) is a multi-government policy forum established in 2009 under the Clean Energy Ministerial (CEM), dedicated to accelerating the deployment of EVs worldwide (CEM, 2017).

As of May 2017, the EVI counted ten member governments (Canada, China, France, Germany, Japan, the Netherlands, Norway, Sweden, the United Kingdom and the United States). China and the United States are currently co-leading the EVI,[8] and the IEA is the co-ordinator of the initiative. India and Korea are also engaged in the EVI's activities and in 2017 shared their national data on road-transport electrification. South Africa was an EVI member up to 2016 and remains an active observer of the initiative's activities.

Collectively, the EVI members account for most of the global EV market and stock (95% of all electric car registrations and 95% of the total stock monitored in this assessment).

The EVI has established partnerships with AVERE, the Climate Group, the German Corporation for International Cooperation (GIZ), GreenTech Malaysia, the ICCT (hosting the secretariat of the International Zero-Emission Vehicle Alliance), the IEA Hybrid and Electric Vehicle Technology Collaboration Programme (IEA HEV TCP), the International Renewable Energy Agency (IRENA), King Mongkut's University of Technology Thonburi (Thailand), the Lawrence Berkeley National Laboratory (LBNL), the United States National Renewable Energy Laboratory (NREL), the United Nations Environment Programme (UNEP), the United Nations Human Settlements Programme (UN Habitat), the United Nations Industrial Development Organization (UNIDO) and Urban Foresight.

The EVI brings together representatives of its member governments and partners twice per year. It has proven to be as an effective platform for the exchange of information, action and communication about EVs and has helped to inform policy makers and the public about EV deployment.

To date, the EVI has developed analytical outputs that include the *Global EV Outlook*, started in 2013 and now an annual series (EVI, 2016a, 2015a, 2013), and two editions of the *EV City Casebook* (EVI, 2014, 2012), with a focus on initiatives taking place at the local administrative

[7] Air quality issues are causing health problems in many cities globally, resulting in millions of premature deaths each year and inflicting major costs to the global economy (WHO, 2016; IEA, 2016).

[8] United States' leadership under review.

level. The EVI successfully engaged private sector stakeholders in roundtables in Paris in 2010, in Stuttgart in 2012 and at COP21 in 2015 (EVI, 2015b) to discuss the roles of industry and government in the EV market as well as the opportunities and challenges ahead. The EVI has also been instrumental in mobilising actions from participating governments, contributing major analytical inputs to the Paris Declaration on Electro-Mobility and Climate Change and Call to Action, released at COP21 (UNFCCC, 2015a), and developing the EVI Government Fleet Declaration (EVI, 2016b), announced at COP22 in Marrakech in 2016.[9]

### *The EV30@30 campaign*

The EV30@30 campaign, launched at the Eighth Clean Energy Ministerial in 2017, redefined the EVI ambition by setting the collective aspirational goal for all EVI members of a 30% market share for electric vehicles[10] in the total of all passenger cars, light commercial vehicles, buses and trucks by 2030.

The campaign includes several implementing actions aimed at helping achieve this goal in accordance with the priorities and programmes developed in each EVI country. These actions include:

- supporting the deployment of chargers and tracking progress
- galvanising public and private sector commitments for EV uptake in company and supplier fleets
- the scale-up of policy research, including policy efficacy analysis, information and experience sharing, and capacity building
- establishing the Global EV Pilot City programme, a global co-operative programme aimed at facilitating the exchange of experiences and the replication of best practices for the promotion of EVs in cities.

## Scope of this report

This report conveys information collected from EVI members and partners to analyse the global evolution of the EV market, the growth of the EV stock and the deployment of EVSE. It includes a review of policy actions on EVs and EVSE and analyses market developments in relation to changes in the policy framework. It also provides an update on RD&D developments, benefiting from the close relationship between the EVI and the IEA HEV TCP and the technology experts participating in it.

This report concerns mainly the electric car market and does not cover other transport modes at the same level of detail. The focus on the car market is due to both its dynamism and the wider availability of data for this vehicle group. Targeted details on two-wheelers, three-wheelers, LSEVs and buses, with a focus on some of the most significant cases, including those having implications for future market developments, complement the information on cars.

The countries covered include Canada, China, Iceland, India, Japan, Korea, Lichtenstein, Norway, Switzerland, Turkey, the United States and each of the member countries of the European Union (EU 28). Figure 4 provides a visual summary of this list, showing the EVI members, countries that

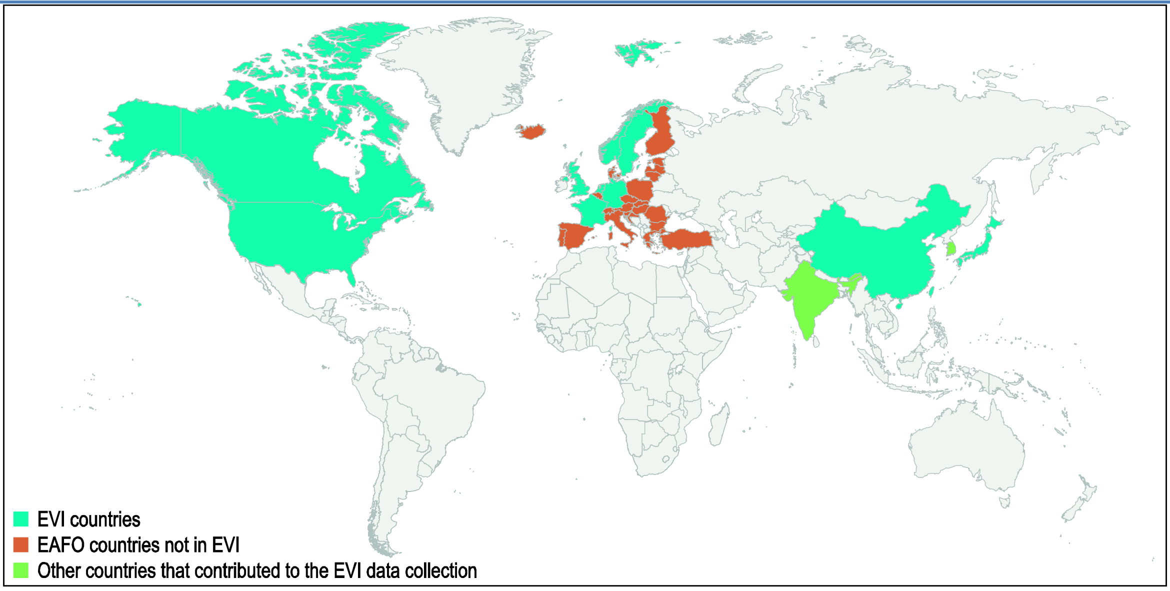
[9] The EVI Government Fleet Declaration gathers statements on measures aiming to introduce low-emissions vehicles, including electric vehicles, from eight EVI member countries. The IEA estimates that the commitments voiced in the EVI Government Fleet Declaration could lead to the introduction of approximately 200 000 low-emission vehicles between 2016 and 2020, accompanied by a large potential for raising awareness from the public and supporting EVSE deployment and the entry of new e-mobility service providers into the market.

[10] Including BEVs, PHEVs and FCEVs.

report data to the European Alternative Fuels Observatory and countries that reported data to the EVI for the preparation of this publication. The results in this publication cover all EVI members individually. With a few exceptions, data for all other countries have been reported and analysed as a single aggregate.



**Figure 4 • EVI member countries and country coverage of the *Global EV Outlook 2017***




Note: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

**Key point:** The *Global EV Outlook 2017* covers 39 countries, accounting for most of the global electric car stock.

## Data sources

The main sources of information used in this report include submissions from EVI members, statistics and indicators available from the European Alternative Fuels Observatory (EAFO, 2017a) for European countries that are not members of the EVI (Figure 4), data extracted from commercial databases (IHS Polk, 2016; MarkLines, 2017) and information released by relevant stakeholders (ACEA, 2017a, 2017b; EEA, 2017).

# EV deployment

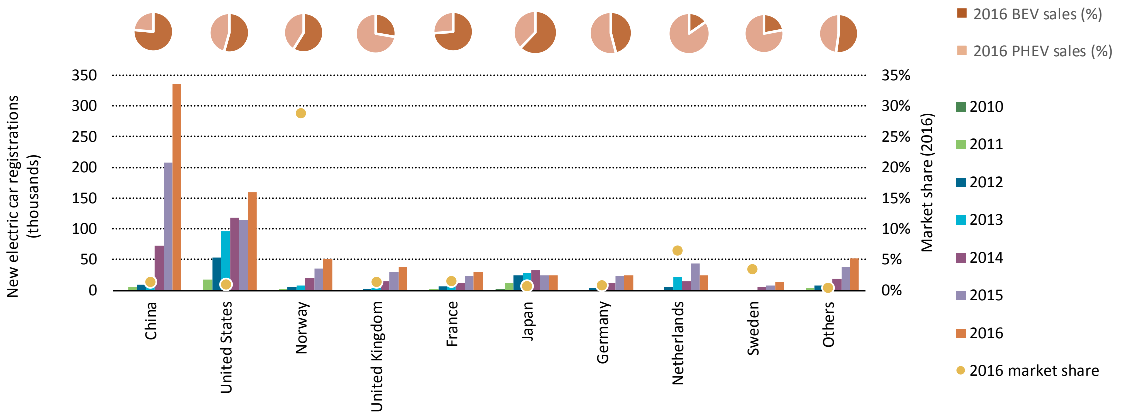
This section reviews the latest developments in new registrations and the stock of EVs, looking primarily at electric cars and focusing on the developments that took place in 2016 as well as the trends since 2010. Stock and sales figures are assessed against policy support schemes and international, national or private commitments on EV deployment for the 2020, 2025 and 2030 time horizons (depending on national settings). EV deployment is also assessed against the ambition of the EV30@30 campaign.

## Electric cars

### *Market evolution*

Registrations of electric cars hit a new record in 2016, with over 750 thousand sales worldwide. However, sales for 2016 showed a slowdown in the market growth rate compared with previous years to 40%, making 2016 the first year since 2010 that year-on-year electric car sales growth fell below 50%. Despite the decline, maintaining the 2016 rate of growth over the following years will still allow for meeting the sales and stock objectives of the 2DS for 2025.

**Figure 5 • Electric car sales, market share, and BEV and PHEV sales shares in selected countries, 2010-16**




Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2017a), IHS Polk (2016), MarkLines (2017), ACEA (2017a, 2017b) and EEA (2017).

**Key point:** The two main electric car markets are China and the United States. Six countries reached EV market shares of more than 1% in 2016: Norway, the Netherlands, Sweden, France, the United Kingdom and China.

China was by far the largest electric car market in 2016, with 336 thousand new electric cars registered. Electric car sales in China were more than double the amount in the United States, where 2016 electric car registrations rebounded to 160 thousand units after a slight drop in the previous year (Figure 5). European countries accounted for 215 thousand electric car sales.[11] Both globally and in the European Union, the electric car market is still concentrated in a limited number of countries. In Europe, most of the electric cars sold in 2016 were registered in just six countries: Norway, the United Kingdom, France, Germany, the Netherlands and Sweden. Globally, 95% of electric car sales are taking place in just ten countries: China, the United States, Japan, Canada and the six leading European countries.

[11] In this case, European countries include all the countries geographically located in Europe that report data to the EVI and the EAFO (see Figure 4).

In 2016, six countries achieved an electric car market share above 1% of their total PLDV sales. Among these, Norway was the incontestable global leader, with a 29% market share, the result of a favourable policy environment in recent years comprising a large range of incentives, from tax breaks and exemptions to waivers on road tolls and ferry fees. Norway was followed by the Netherlands, with a 6.4% electric car market share, and Sweden with a 3.4% share. China, France and the United Kingdom all had electric car market shares close to 1.5%. China and France also have BEV-oriented markets, and roughly three-quarters of their 2016 electric car sales were BEVs, and only one-quarter were PHEVs. In contrast, in the Netherlands, Sweden and the United Kingdom, the majority of electric cars registered in 2016 were PHEVs. In Japan, Norway and the rest of the world, on average, electric car sales were more equally split between BEVs and PHEVs (Figure 5).



Year-on-year developments between 2015 and 2016 will be further discussed in the following section, with assessments – to the extent possible – against changes in policy support mechanisms.

## *Policy support*

### *Overview of existing support mechanisms for electric car deployment*

At this stage of electric car market deployment, policy support is still indispensable for lowering barriers to adoption. A supportive policy environment enables market growth by making vehicles appealing for consumers, reducing risks for investors and encouraging manufacturers willing to develop EV business streams on a large scale to start implementing them. In particular, these factors enable a wider model offer range to consumers, which is key to spurring sales growth. Policy support mechanisms can be grouped into four major categories: support for the research and development of innovative technologies; targets, mandates and regulations; financial incentives; and other instruments (primarily enforced in cities) for allowing increases in the value proposition of EVs. Public procurement (leading by example) is also well suited to facilitating EV uptake.

#### Research support

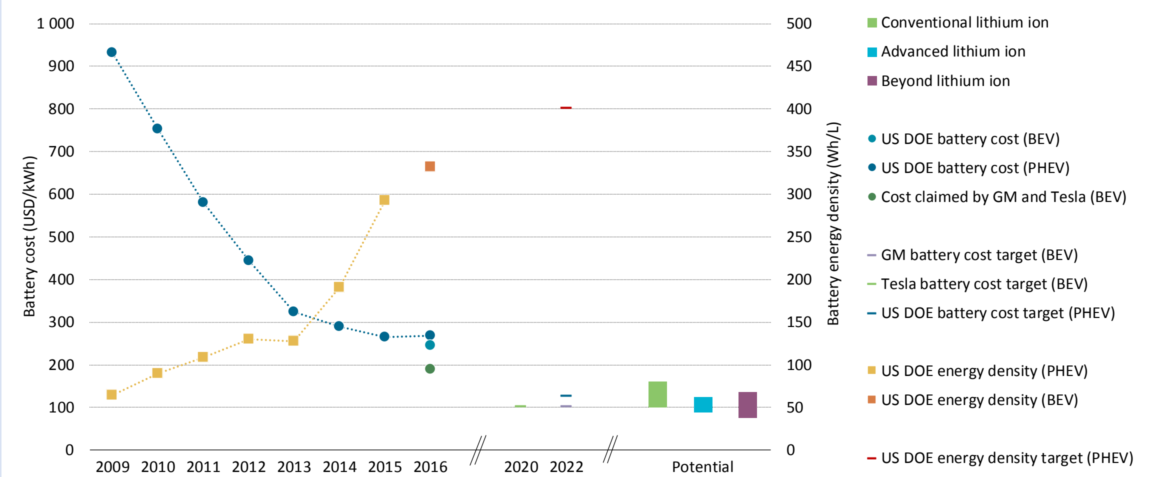
Research support is key to achieving cost declines and performance improvements and is best conceived when coupled with other instruments that allow the scale-up of production. Box 1 provides an assessment of the recent developments in battery cost and performance. RD&D and mass production prospects are leading to rapid cost declines and performance improvements. This is confirmed by the gap between commercial applications and batteries currently being researched, increasing production volumes resulting from electric car market growth, the larger pack sizes that are accompanying increased electric driving ranges, and cost reductions expected for all families of battery technologies assessed by the United States Department of Energy (US DOE) (see Figure 6). These same elements provide encouraging signs for achieving the targets set by carmakers and the US DOE for the early 2020s.

**Box 1 • Recent developments in battery cost and performance**

Figure 6 shows an updated assessment of the battery cost developments already included in earlier editions of the *Global EV Outlook*. This update includes information for 2016 on the costs and volumetric energy densities of batteries currently being researched, as well as the ranges of cost reductions that can be expected from the three main families of battery technologies: conventional lithium ion; advanced lithium ion, using an intermetallic anode (i.e. silicon alloy-composite); and technologies going beyond lithium ion (lithium metal, including lithium sulphur and lithium air).

The 2016 cost and energy density assessment draws from the results developed by the US DOE (Howell, 2017). The assessment aims to reflect the production cost of technologies that are currently being researched once they achieve commercial-scale, high-volume production (US DOE, 2017). The US DOE estimate is higher than the USD 180/kWh to USD 200/kWh range of battery pack costs announced recently by GM and LG Chem (Ayre, 2015) or Tesla and Panasonic (Field, 2016; Lambert, 2016a, 2016b) for batteries that will be used in new EV models. The estimates are also lower than the costs estimates for commercially available technologies reported in other assessments, which range between USD 300/kWh (Slowik et al., 2016) and USD 500/kWh (US DOE, 2017). Overall, this confirms that technologies currently in the R&D stage have better performance than those available on the market. Since the cost estimates for the scale-up of lab-scale technologies are projections of the expected costs in three to five years for high-volume production (US DOE, 2017),[12] the assessment suggests that battery costs will continue to decline.

**Figure 6 • Evolution of battery energy density and cost**




Notes: Contrary to the results assessed for 2009-15, which targeted PHEV batteries, the 2016 estimates of costs and volumetric energy density by the US DOE (costs are to be interpreted as projections for the high-volume production of technologies currently being researched) refer to a battery pack that is designed to deliver 320 km of all-electric range and is, therefore, suitable for BEVs. The latest update of this cost assessment was developed accounting for an advanced lithium-ion technology (with silicon alloy-composite anode). Being a technology that is still being researched today, this is currently deemed to have a greater cost but also a larger potential for cost reductions compared with conventional lithium-ion technologies.

Sources: Howell (2017), EV Obsession (2015) and Cobb (2015a).

**Key point:** Prospects for future cost reductions from the main families of battery technologies confirm the encouraging signs in cost and performance improvements observed over the past decade.

Expansions in production volumes and pack size bear the capacity to reduce unit costs (Howell, 2017). According to the US DOE, increasing production volumes from 25 000 units to 100 000 units for a BEV (100 kWh) battery pack allows a cut in battery pack production costs per kWh by 13%. Other studies confirm that production volume is a key factor in battery pack cost reduction: battery pack production volumes of over 200 000 battery packs per year are estimated to cost USD 200/kWh or less. This is roughly one-third lower than the USD 300/kWh estimated for production volumes ranging between 10 000 and 30 000 units in 2015 (Slowik et al., 2016).

Increasing the pack size from 60 kWh to 100 kWh (roughly reflecting, in the case of an average car sold in the United States, an increase in range from 200 km to 320 km) would also lead to a 17% reduction in cost per kWh at the pack level (Howell, 2017).

[12] Looking at the historical assessment of technologies being researched (Figure 6) against the costs estimated for commercially available applications today also suggests that lab-scale technologies tend to be three to five years ahead when compared with the average commercial technologies.

### Targets, mandates and regulations

Targets are important in the policy-making process because they help move the focus of the discussion to policy implementation and capacity building, moving beyond the debate on the opportunity to regulate. In the transport sector, the Global Fuel Economy Initiative, which helped ensure that fuel economy regulations cover 80% of the global vehicle market, is an example of how this change in focus resulted in measurable progress towards the achievement of policy goals (GFEI, 2016). The EV30@30 campaign, which sets a collective aspirational goal for all EVI members of a 30% EV market share by 2030,[13] is a significant step in this direction.



Mandates and regulations build on the definition of regulatory targets to provide a clear signal to manufacturers and customers as they set a medium- to long-term vision for defining the evolution of vehicle characteristics. Key measures in this category include zero-emission vehicle (ZEV) mandates and fuel economy regulations.

- ZEV mandates are regulatory requirements (possibly embedding a system of tradable credits) for automakers to sell a set portion of ultra-low or zero-emission vehicles. They aim to promote RD&D efforts for marketing ultra-low and zero-emission vehicles. ZEV mandates were pioneered in California (CARB, 2017), are enforced in several states in the United States (UCS, 2016) in the province of Quebec, Canada, and are now being considered in China (Lambert, 2016c).
- Acting directly on one of the key vehicle design parameters, fuel economy regulations are effective in stimulating the adoption of energy-efficient and low-carbon technologies.[14] If tightened beyond the efficiency potential available from improved ICEs and hybrids, they will be one of the main policy drivers for enabling the transition to electric mobility.[15] The latter is also facilitated by clear, long-term indications of the evolution of the regulations and a coherent scope in terms of market coverage. Such signals are not always embedded in the existing frameworks.

### Financial incentives

Financial incentives directed at electric car customers and users are essential for reducing the purchase cost and total cost of ownership (TCO) gap between electric and conventional cars. They are relevant for private customers, company cars and fleets, both in the public and private sectors.

Despite rapidly decreasing battery costs since 2009 (Figure 6), electric car battery packs are still a major cost component and drive up retail prices. Financial incentives are important in the current phase of electric car technology deployment to initiate and reinforce a positive feedback loop that, through increasing sales, production scale-ups and technology learning, will support cost reductions for batteries and other components.

EV incentives can take the form of direct rebates, tax breaks or exemptions, and can be framed in technology-neutral, differentiated taxation that favours low-emission vehicles according to their GHG and pollutant emission performance and penalises vehicles with high environmental costs. Many countries, including 20 EU member states – such as the Scandinavian countries, where

[13] This includes BEVs, PHEVs and FCEVs and is a share of the total of all passenger cars, light commercial vehicles, buses and trucks.

[14] This is the case if reliable test procedures ensure consumer confidence and fair competition among OEMs.

[15] Fuel economy regulations can include provisions to give greater weight to electric cars in the calculation of corporate averages. This provides incentives to OEMs to start developing electric car production, but it also reduces the average fuel economy improvement (and associated benefits) delivered in the timeframe targeted by the regulations. In order to manage this drawback, these provisions shall be defined in conjunction with the definition of the overall policy target of the fuel economy regulation. In any case, they shall be limited to the early market deployment of electric cars.

vehicle taxes tend to be high (ACEA, 2016) – Brazil, Canada, China and South Africa (GFEI, 2017), currently impose differentiated taxes on vehicle registration and/or circulation based on their fuel economy or $CO_2$ emissions performance.



Although all EVI countries do apply purchase and circulation subsidies, a comparison of the purchase cost and the TCO for electric cars and vehicles using ICEs across European markets suggests that financial incentives are most effective when they minimise the EV purchase premium and come with a TCO advantage compared with ICEs (Hoy and Weken, 2017).

### Policies for increasing the value proposition of electric cars

Electric car deployment can also be supported by increasing the appeal of electric cars over competing alternatives and providing advantages in terms of reduced fees, privileged access and time savings to electric car drivers. These targeted policies are best developed at the municipal level and adapted to the unique, local mobility conditions of each urban area, although they can be facilitated by national EV policy support frameworks. The following are examples of policies for increasing the value proposition of electric cars for drivers.

- **Waivers on regulations that limit the availability of licence plates for ICE vehicles**.

  These measures consist of total or partial exemption for low-emission vehicles, particularly electric cars, from increment control measures (such as lotteries or auctions, or a combination of both) restricting the availability of licence plates in urban agglomerations. They are in place in major Chinese cities.[16]

- **Exemptions from access restrictions to urban areas**.

  These measures take the form of access allowances, which are granted only to vehicles that meet strict exhaust emission standards and have already been widely applied in European cities (see Urban Access Regulations, 2017), and exemptions from other road space rationing measures, such as alternate-day travel based on licence plate numbers. The initiative recently announced by Paris and Mexico City to implement a diesel ban in 2025 (C40, 2017) and incentivise the use of electric, hydrogen and hybrid vehicles is also an example of action in this category.

- **Exemptions from usage fees for specific portions of the road network** (e.g. parking fees, road tolls and other fees incurred from vehicle use).

  One of the most iconic measures of this nature has been announced by the municipality of London. It consists of the Ultra Low Emission Zone (ULEZ), set to come into force in 2019 or 2020 at the latest (TfL, 2017a). The ULEZ is an area in central London within which all cars, motorcycles, vans, minibuses, buses, coaches and heavy-goods vehicles (HGVs) will need to meet exhaust emission standards (ULEZ standards) or pay a daily charge to travel. Improvement in air quality is the reason for the introduction of this measure. The ULEZ is complemented by actions aiming to promote walking, cycling, public transport and the use of sustainable freight deliveries. The London Congestion Charge (TfL, 2017b), already in place, also offers a 100% discount for electric cars.

- **Dedicated parking and access to publicly available charging infrastructure**.

  Electric car support measures relative to dedicated parking and public access to charging infrastructure are generally best implemented either at the local or municipality level or via private actions (possibly supported by public incentives and regulations) and are further discussed in the section on EVSE.

[16] Chinese cities where such measures have been adopted include Beijing, Guangzhou, Guiyang, Hangzhou, Shanghai, Shenzhen and Tianjin. See Table 2 in EVI (2016a) for details.

- **Allowances to access bus lanes and high-occupancy vehicle (HOV) lanes**.

  Measures favouring EV access to the road network over ICEs can have sizeable impacts not only on the increased short-term value of electric cars (imputable to greater usage opportunities) but also on the economics of electric cars over time. Prospects of a travel ban for polluting vehicles, for instance, have the significant potential to lower the depreciation rate of electric cars compared to competing alternatives, increasing their economic competitiveness on the second-hand market.



### Fleet procurement

Fleet operators, both in public authorities and the private sector, can contribute significantly to the deployment of EVs: first through the demand signals that they can send to the market, and second thanks to their broader role as amplifiers in promoting and facilitating the uptake of electric cars by their staff and customers.

Mandates and tenders from national and local authorities can foster EV uptake in large public fleets of vehicles, including municipal cars, service vehicles (such as garbage trucks) and vehicles used for public transport.

The EVI Government Fleet Declaration (EVI, 2016b) provides an overview of the actions that have already been undertaken by EVI countries regarding their public fleets, including measures taken by the central governments and local authorities. It also includes plans for the scale-up of public procurement and a call for action to non-state actors for the development of similar initiatives.

Partnerships between public authorities willing to mobilise the deployment of clean vehicle fleets can help to minimise the costs of public procurement. A concrete example of the cost opportunity is the joint action led by four cities in the United States – Los Angeles, Seattle, San Francisco and Portland, and now signed by 30 cities – to start a partnership to mass-purchase EVs for their public vehicle fleets (Lambert, 2017a; Ryan, 2017). The vehicles include not only regular passenger cars but also police cruisers, street sweepers and trash haulers. The order is currently seeking up to 114 thousand vehicles, a magnitude that is comparable with the 160 thousand EVs sold in the United States in 2016 and that will contribute to strengthening EV registrations.

Initiatives taken by public authorities can also be mirrored by commitments made by the private sector to embrace electric mobility. Initially, the rationale for this choice can be explained by the possibility to strengthen the environmental performance of companies and the capacity to show leadership in taking action on issues such as local air pollution, noise, energy diversification and climate change. As costs decline, this also translates into economic advantages, especially for fleets with high mileages.

The EV30@30 campaign builds on existing and forthcoming commitments on public and private fleets to stimulate EV deployment.

## *Key developments in 2016*

The electric car market in 2016 experienced significant changes compared to 2015. Table 1 provides a high-level overview of these changes, bringing together qualitative indicators on the transformations of financial support mechanisms for electric car purchases between 2015 and 2016 and year-on-year changes in BEV and PHEV registrations.

**Table 1 • BEV and PHEV incentives developments in a selection of countries, 2016**

| Country | 2015 vs. 2016 policy developments | | 2015 vs. 2016 sales growth | | 2016 sales | |
|---|---|---|---|---|---|---|
| | BEV | PHEV | BEV | PHEV | BEV | PHEV |
| China | ~ | | 75% | 30% | 257 000 | 79 000 |
| United States | ~ | | 22% | 70% | 86 731 | 72 885 |
| Norway | ~ | ↗ | 6% | 164% | 29 520 | 20 660 |
| United Kingdom | ~ | | 4% | 42% | 10 509 | 27 403 |
| France | ~ | | 26% | 36% | 21 758 | 7 749 |
| Japan | ~ | | 48% | -34% | 15 461 | 9 390 |
| Germany | ~ | | -6% | 20% | 11 322 | 13 290 |
| Netherlands | ~ | ↘ | 47% | -50% | 3 737 | 20 740 |
| Sweden | ~ | ↘ | 0% | 86% | 2 951 | 10 464 |
| Canada | ~ | | 19% | 147% | 5 220 | 6 360 |
| Denmark | ↘ | | -71% | -49% | 1 218 | 182 |
| Korea | ~ | | 75% | -40% | 5 099 | 164 |

Notes: The symbol ~ indicates no major observed change in electric car support incentives between 2015 and 2016; an upward arrow indicates an increase in electric car support incentives; a downward arrow indicates a drop in electric car support incentives. The green and red colours indicate a probable correlation between the developments in electric car support incentives and BEV and PHEV sales in 2016 compared to the previous year. Greater details on the policy context are available in the main text.
PHEV sales in Denmark and Korea are available from primary data sources in conjunction with hybrid and electric vehicles (HEVs). Consequently, PHEV sales shown in this table for Denmark and Korea rely primarily on estimations based on the sources listed below and may be underestimated.

Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2017a), IHS Polk (2016), MarkLines (2017), ACEA (2017a, 2017b) and EEA (2017).

**Key point:** The capacity to couple key changes in electric car deployment policies effectively with the evolution of BEV and PHEV registrations between 2015 and 2016 broadly confirms that electric car market mechanisms are still largely driven by policy support.

The following section elaborates further on the information in Table 1 and summarises the key policy developments together with explanations on how some of the policy changes have influenced the evolution of BEV and PHEV registrations. The capacity to couple key changes in EV deployment policies and the evolution of BEV and PHEV registrations between 2015 and 2016 outlined here broadly confirm that EV market mechanisms are still largely driven by policy support.

- Chinese policies continued to provide strong financial and non-financial incentives to EV adoption in 2016. Exemptions from acquisition and excise taxes ranged between CNY 35 000 and CNY 60 000 (USD 5 000 to USD 8 500). Local and regional authorities can complement these within the limit of 50% of the central subsidies. Large Chinese cities also allow total or partial waivers from licence plate availability restrictions (EVI, 2016a). The combination of imposing licence plate restrictions, encouraging consumers to buy electric cars, and offering financial incentives – making electric cars financially accessible – explains the strong sales volumes (336 000 cars) and growth rate (40%) in 2016 compared to 2015 (Table 1). In its 2016-20 plan, Subsidy Schemes and Product Technology Requirements for the Promotion of New Energy Vehicles, the Chinese government announced that subsidies for EVs would be reduced by 20% from 2017 onwards, acknowledging the intention to constantly adjust and improve its policies for an optimised market response (MoF, 2017). Despite these changes, China's electric car market continued to grow in early 2017 (Pontes, 2017).

- In Norway, electric cars are exempt from acquisition tax, representing around NOK 100 000 (USD 11 600) (OECD, 2015). BEVs are exempt from the 25% value-added tax (VAT) on car purchases. This environment, coupled with a large number of waivers on fees such as road tolls and ferries, continues to provide a highly favourable environment for electric car uptake and for BEVs in particular. BEV taxation should remain unchanged until 2020, while higher purchase rebates and tax waivers were introduced for PHEVs in 2016 compared to 2015. Free parking for electric cars has no longer been applicable nationwide since 2016. BEV sales reached a record high in 2016 but did not grow significantly compared with 2015. On the other hand, PHEV sales registered remarkable growth and more than doubled in just one year. This was consistent with the change in policy support. Other factors that may have influenced sales include changes in BEV and PHEV model availability and an increased interest in electric cars from customers who more frequently cover long-distance trips (in this case potentially favouring PHEV sales).
- In Japan, a new subsidy scheme was introduced in 2016 that grants progressively higher subsidies as the electric range of the model increases, with the maximum subsidy set at JPY 850 000 (USD 7 700). For a Nissan Leaf with a 30-kWh battery, the purchase incentive amounts to JPY 330 000 (USD 3 000). BEV sales (typically with larger batteries and higher electric ranges than PHEVs) in 2016 increased by almost 50%, while PHEV sales dropped by 34%. Other factors that explain this market evolution include the introduction of the new Nissan Leaf in 2016, as well as the negative influence of allegations of falsifying fuel economy standards of Mitsubishi models.
- The Netherlands have a differentiated $CO_2$-based taxation scheme for which taxation rates are gradually evolving through 2020 (the rates for each year to 2020 have already been announced) (Energielabel, 2016). The changes primarily affect PHEVs, which will be subject to tax rates that will keep increasing compared with the rates in 2015. Zero-emission cars are exempt from registration tax, while cars with $CO_2$ emissions per km corresponding to a PHEV were subject to a EUR 6 per g $CO_2$/km tax rate in 2016 – this will increase to EUR 20 per g $CO_2$/km in 2017. Tax rates for BEVs will not change. Similar revisions are being made for the taxation of the private use of company cars, an important element in the Netherlands given that company car sales represented about the same proportion as private car sales in 2014. ZEVs pay 4% income tax on the private use of a company car, while the rate for PHEVs increased from a 7-14% range in 2015 to a 15-21% range in 2016, and will increase further to 22% (i.e. the same rate as conventional cars) by 2017. There is a strong likelihood that these changes in taxation are one of the reasons for the strong drop in PHEV sales, from a record-high 10% of total car sales in 2015 to 5% in 2016. This trend continued in early 2017 given the even larger tax rates applied in comparison to 2016 (EAFO, 2017b).
- The Swedish government decided to cut the purchase rebate offered to PHEVs, from SEK 40 000 (USD 4 500) in 2015 to SEK 20 000 (USD 2 250) in 2016 (for BEVs, this has been maintained at SEK 40 000 [USD 4 500] since 2011). This coincides with a large growth in PHEV sales in 2016 compared to 2015 (86%), while BEV sales have remained steady. The PHEV sales growth, in spite of the significant cut in purchase incentives, could be due to the large share of PHEVs sold as company cars and the incentives resulting from a reduction in value of the “fringe benefits” allowed for plug-in cars compared to conventional cars of the same class (estimated savings of SEK 1 000 [USD 110] or more per month). Additionally, the release of a larger offer of PHEV models in the past couple of years, such as the plug-in Volkswagen Passat, the Mitsubishi Outlander and the plug-in Volvo V60, likely influenced consumers’ interests (Kasche, 2017).

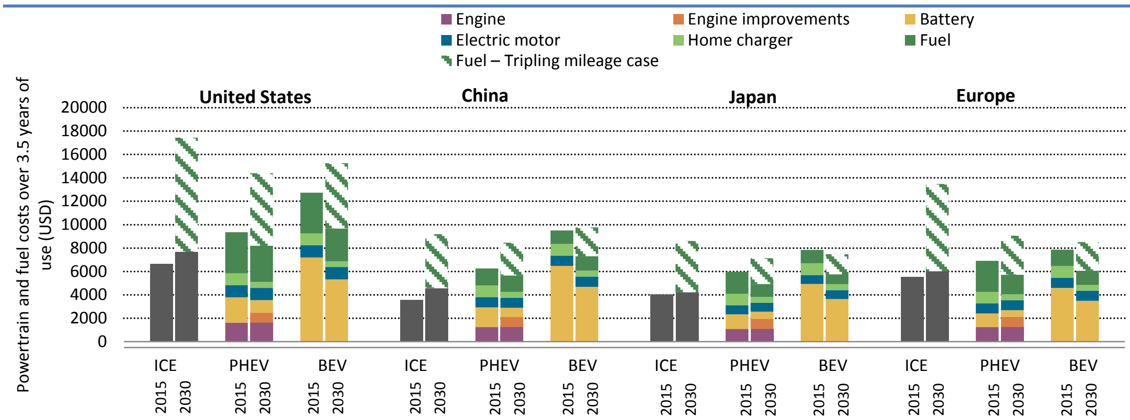


- Denmark initiated in 2016 the phasing-in of registration taxes for electric cars after several years of full exemption. In 2016, electric cars were subject to 20% of the full registration tax rate normally applied to conventional cars. This rate will be applicable to the next 5 000 electric car units sold or until the end of 2018. It will continue increasing until 2022 when full taxation will be applied to electric cars again. In parallel, Denmark, which had been a leader in electrification initiatives since 2008, mainly through public procurement programmes supported by the government, stopped these activities in 2016. Both these factors combined are likely to have been the main drivers of the drop in electric car sales (-68%) observed in 2016 (HEV TCP, forthcoming). As of 2017, Denmark will introduce a purchase tax rebate on electric cars based on battery capacity of USD 225/kWh applicable to a maximum of 45kWh, representing USD 10 000.

## *Future prospects*

Figure 7 provides an overview of the TCO of PLDV technologies in major global regions in 2015, taking into account 3.5 years of fuel use and the same depreciation rate across all technologies. The figure also shows projections for 2030 developed according to the IEA 2DS.

**Figure 7 • Comparative cost of PLDV technologies by country/region in the 2DS, 2015 and 2030**




Notes: Vehicle travel per year, powertrain costs and fuel costs reflect the regional assumptions of IEA (2017b): 2015 powertrain investment costs for European vehicle characteristics range from USD 3 500 for ICEs to USD 7 800 for PHEVs and USD 12 400 for BEVs. The 2030 powertrain investment costs for European vehicle characteristics range from USD 4 700 for ICEs to USD 7 000 for PHEVs and USD 9 600 for BEVs. Powertrain costs in other countries are adapted to domestic vehicle characteristics. The results shown also reflect a 60% depreciation and a uniform assumption of a 20% tax on vehicle purchases. Insurance and maintenance costs are not included. A USD 1 000 cost for the installation of a home charger is included in the TCO for PHEVs and BEVs in 2015. By 2030, this cost drops to USD 500. In 2015, the battery pack cost is USD 200/kWh for BEVs and 255 USD/kWh for PHEVs. In 2030, the battery pack cost decreases to USD 100/kWh for BEVs and USD 125/kWh for PHEVs. BEV batteries have a range of 200 km in 2015; PHEV batteries have a range of 40 km. The electric range increases to 350 km for BEVs and 46 km for PHEVs by 2030. In 2015, PHEVs drive 30% of their annual mileage on the electric motor. This rate increases to 80% by 2030. "Fuel – tripling mileage case" refers to the fuel cost increment imputable to a tripling of the average annual mileages considered in the 2DS (this case assumes the same depreciation rate as the base case). The 2030 fuel cost includes a tax of close to USD 80/t $CO_2$. The oil price in 2030 is assumed to be USD 85/barrel.

Source: IEA (2017a), IEA Mobility Model, March 2017 version.

**Key point:** In 2015, electric car costs were higher than those for ICEs in all regions. By 2030, BEVs and PHEVs will become fully cost competitive with ICEs in Europe, where fuel taxes are estimated to be high and vehicle attributes (namely power) more favourable to electrification than in other regions. High yearly mileage electric cars have clearly lower first-owner TCOs for almost all cases when compared with ICEs. This underlines the interesting synergies between shared mobility services and vehicle electrification.

The 2015 assessment shows higher cost profiles for electric cars than ICEs in all regions. This is mainly due to battery costs, which despite their rapid decline in the past decade, are still responsible for higher purchase costs compared to ICEs of comparable power and size. This confirms that in the short-to-medium term, purchase subsidies, tax rebates and tax exemptions will remain key levers for influencing electric car market development. Subsidies will have a major influence on the possibility of lowering the TCO for first-car owners, bringing it closer to the competitiveness threshold with ICEs.

Under the 2DS, continuous improvements in battery costs and performance allow increased BEV ranges while reducing battery prices. At the same time, stringent emission regulations increase ICE costs, while increasing taxes on fossil fuels (reflecting their $CO_2$ content) increase ICE fuel costs. By 2030, BEVs and PHEVs become fully cost-competitive with ICEs in Europe, where fuel taxes are high and vehicle attributes (namely power) are more favourable to electrification than in other regions. The TCO of BEVs and PHEVs approaches the cost competitiveness threshold in other regions. The TCO gap between electric cars and ICEs tends to narrow as battery technologies deliver on cost and performance expectations. Given their energy efficiency and diversified energy mix used on power generation, leading to lower price fluctuations for electricity than for petroleum fuels, BEVs and PHEVs are favoured because of higher oil prices. $CO_2$ taxes on fossil fuels also favour the economic competitiveness of BEVs and PHEVs and reduce the uncertainty borne by oil price fluctuations.



The narrowing cost gap between electric cars and ICEs suggests that as electric car sales keep growing in the 2020s, governments will need to gradually revise their approach to electric car support, phasing out incentives in cases where BEVs and PHEVs actually rival ICE costs. Differentiated taxes based on environmental and health-related performance may need to remain in place, primarily to correct market failures (despite a cost increment for the first owner, electric cars deliver net societal savings over their entire lifetime). The difficulty in achieving full competitiveness for first owners in many of the global regions also suggests that other policy instruments (including fuel economy regulations and local measures, such as differentiated access to urban areas) will remain important in supporting the electric car uptake needed to meet the targets characterising a low-emission future.

Figure 7 also shows, in the tripling mileage case, that electric cars with a higher than average yearly mileage[17] have clearly lower first-owner TCOs by 2030 in almost all cases when compared with ICEs due to rapidly increasing fuel costs in the case of ICEs when mileages grow. This underlines interesting synergies between shared mobility services (particularly relevant in cities) and vehicle electrification. It also indicates that the support of concepts promoting urban mobility as a service (provided they are well integrated with public transportation) could be beneficial for supporting the transition to technologies enabling low-carbon and low-emission mobility.

## *Vehicle stock*

The global electric car stock surpassed 2 million units in 2016 after crossing the 1 million vehicle threshold in 2015 (Figure 8). Despite a continuous increase in the electric car stock, annual growth rates have been consistently decreasing since 2011. In 2016, stock growth was 59%, down from 76% in 2015 and 84% in 2014. BEVs still account for the majority of the electric car stock at 60%. Their share did not change significantly since 2012 and kept fluctuating around this value.

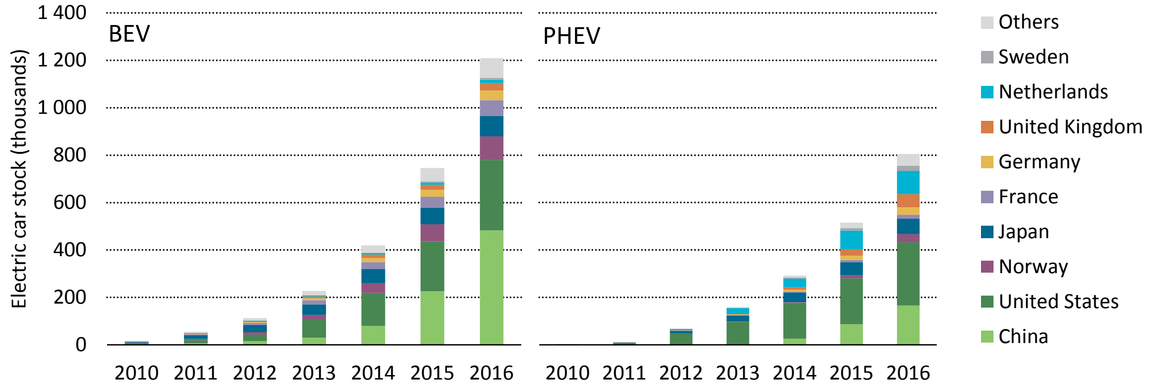
[17] The estimation for a higher yearly mileage (triple the average typical mileage in this analysis) does not attempt to include the effect on costs of larger battery capacity, battery repair or replacement that could be needed to accommodate a higher number of charge and discharge cycles, nor other costs that could be imputable to designs allowing compliance with this usage profile without compromising the performance of the battery. It also excludes (for all powertrain options) the effects on depreciation due to higher vehicle mileage.

When compared with the global car stock, the global electric car stock tracked in this report still accounts for a small fraction, 0.2%, of the total PLDVs in circulation worldwide.

China surpassed the United States in 2016 in total electric car stock, becoming the country with the most EVs on its road network. This evolution is primarily due to China's rapidly growing BEV market, where BEVs have continued to dominate over PHEVs. Since 2014, BEVs stabilised at about 75% of the Chinese electric car stock share. China and the United States make up 60% of the global electric car stock. European countries, combined, account for most of the rest, representing 28% of the global total. Like electric car sales, the global stock is still concentrated in a few markets. The top five countries account for 80% of the total, while the top ten countries account for 96%.



**Figure 8 • Evolution of the global electric car stock, 2010-16**




Notes: The electric car stock shown here is primarily estimated on the basis of cumulative sales since 2005. When available, stock numbers from official national statistics have been used, provided good consistency with sales evolutions.

Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2017a), IHS Polk (2016), MarkLines (2017), ACEA (2017a, 2017b) and EEA (2017).

**Key point:** The electric car stock has been growing since 2010 and surpassed the 2-million-vehicle threshold in 2016. So far, BEV uptake has been consistently ahead of PHEV uptake.

The global BEV stock has experienced a higher annual growth rate than that of PHEVs since 2013. In 2016, BEVs grew by 62%, while PHEVs grew by 59%. The narrative changes if China is not considered: when excluding China, the growth rate of the global PHEV stock has been higher than for BEVs since 2009, with only the exception of 2014.

As in the case of sales, different countries have different characteristics. The electric car stock in China, France and Norway is primarily composed of BEVs. The Netherlands is clearly the country with the largest share of PHEVs in its stock, at 88% of the total. A third group of countries, including Canada and the United States, have a fairly even distribution of PHEV and BEVs in their stock.

## *Progress towards deployment targets*

Accelerating the deployment of electric cars until 2020 and during the 2020-30 decade will be essential for reaching the global EV deployment rates compatible with clean mobility and decarbonisation imperatives.

Starting from 2 million electric cars in circulation worldwide in 2016, all IEA scenarios on EV deployment suggest a significant scale-up by 2030 (IEA, 2017b):

- The Reference Technology Scenario (RTS), which reflects projections that respond to policies on energy efficiency, energy diversification, air quality and decarbonisation that have been announced or are under consideration, already projects to have 56 million electric cars in circulation by 2030, 28 times the 2016 stock.

- The 2DS increases the ambition for the number of electric cars in circulation to 160 million. This occurs in a context consistent with a 50% probability to limit the expected global average temperature increase to 2°C.
- Electric car stock projections in the B2DS, targeting the achievement of net-zero GHG emissions from the energy sector shortly after 2060 (see the introduction), reach 25 million by 2020 and exceed 200 million a decade later.



In both the 2DS and the B2DS, BEVs and PHEVs contribute to the decarbonisation of the energy system thanks to an increasing decarbonisation of the electricity grid and high electric driving rates for PHEVs (80% by 2030).

The Paris Declaration on Electro-Mobility and Climate Change and Call to Action, announced at COP21, expresses the ambition to exceed globally the threshold of 100 million electric cars and 400 million electric two-wheelers by 2030 (UNFCCC, 2015a), about a third below the number of electric cars projected in the 2DS and half the EV stock of the B2DS.

In recent years, a number of governments – many of which are involved in EVI activities – have also set national electric car deployment targets as part of their clean energy and mobility ambitions. In 2016, 14 countries had electric car targets in place: Austria, China, Denmark, France, Germany, India, Ireland, Japan, the Netherlands, Portugal, Korea, Spain, the United Kingdom and the United States (where targets have been defined for eight states). Korea is the only country that upgraded its target in 2016, from 200 000 to 250 000 electric cars by 2020, as per the Special Plan for Fine Dust Management, released in June 2016 (MoE, 2016). Denmark is no longer targeting 200 thousand electric cars by 2020 (Rask, 2017). The cumulative assessment of these targets, developed by the EVI (2016a), suggests the deployment of 13 million electric cars among these countries by 2020.[18] Achieving this cumulative target at a global level would require an annual electric car stock growth of 60% per year until 2020, a value comparable to the growth rate observed in 2016. On the other hand, meeting targets aligned with a 2DS pathway to 2020 would require a higher annual rate of increase of 85%. India is also looking at the 2030 horizon with ambitious engagements on vehicle electrification, as the country contemplates to have "most, if not all, vehicles in India […] powered by electricity" (PIB India, 2017). This statement implies that India would leapfrog to electric vehicles as the economy is driving a rapid expansion of the PLDV market in the country and bring over 50 million electric cars on its roads in less than 15 years, to reach just above 50% of the total PLDV fleet projected to be in circulation in the country under the B2DS (IEA, 2017a).

The year 2016 also recorded important announcements on electric car deployment targets from major global OEMs. These included announcements by Tesla, aiming to deploy at least 1 million sales by 2020, or Volkswagen, which unveiled a plan for a significant shift towards the production of electric powertrains and announced no less than 30 electric models to enter the market by 2025 (Volkswagen, 2016). Between 2015 and early 2017, nine global OEMs publicly announced their willingness to create or significantly widen their electric model offer over the next five to ten years. In China, which accounts for one-third of the global electric car stock by 2025 in the IEA 2DS, several Chinese OEMs also announced significant electric car production capacity scale-up plans (CNEV, 2017). A summary of all the announcements that were tracked in this assessment is provided in Table 2. Figure 9 provides an overview of electric car deployment for the next 15 years. The figure pools together indications derived from a range of different scenarios, including three IEA projections and the ambition outlined in the Paris Declaration, and

[18] In 2017 Germany has also expressed doubts on the likelihood of meeting the target of 1 million electric cars on the roads by 2020 (Reuters, 2017). The assessment made in EVI (2016a) includes the German target.

assesses them against targets established by individual countries and announcements from major OEMs.

The assessment of OEM announcements in terms of stock growth, as presented in Figure 9, was developed by taking into account cumulative sales targets at a given point in time, if they were available, or calculating them on the basis of sales targets, assuming a linear development of sales growth from now until the target year (typically 2020 or 2025). In cases where the target year was 2020, the lower bound of the stock growth for 2025 was calculated assuming constant sales, while the higher bound was derived from the application of RTS sales and stock growth to the available information on 2020. In the case of China, the lower bound estimate for 2020 matches the 2 million annual electric car capacity production government target by 2020. The upper bound estimate reflects the growth in production capacity announced by the OEMs, factoring in a 66% capacity utilisation rate.[19]

**Table 2 • List of OEMs announcements on electric car ambitions, as of April 2017**

| OEM | Announcement | Source |
|---|---|---|
| BMW | 0.1 million electric car sales in 2017 and 15-25% of the BMW group's sales by 2025 | Lambert (2017b) |
| Chevrolet (GM) | 30 thousand annual electric car sales by 2017 | Loveday (2016) |
| Chinese OEMs | 4.52 million annual electric car sales by 2020 | CNEV(2017) |
| Daimler | 0.1 million annual electric car sales by 2020 | Daimler (2016a) |
| Ford | 13 new EV models by 2020 | Ford (2017) |
| Honda | Two-thirds of the 2030 sales to be electrified vehicles (including hybrids, PHEVs, BEVs and FCEVs) | Honda (2016) |
| Renault-Nissan | 1.5 million cumulative sales of electric cars by 2020 | Cobb (2015b) |
| Tesla | 0.5 million annual electric car sales by 2018<br>1 million annual electric car sales by 2020 | Goliya and Sage (2016),<br>Tesla (2017a) |
| Volkswagen | 2-3 million annual electric car sales by 2025 | Volkswagen (2016) |
| Volvo | 1 million cumulative electric car sales by 2025 | Volvo (2016) |

Note: Chinese OEMs include BYD, BJEV-BAIC Changzhou factory, BJEV-BAIC Qingdao factory, JAC Motors, SAIC Motor, Great Wall Motor, GEELY Auto Yiwu factory, GEELY Auto Hangzhou factory, GEELY Auto Nanchong factory, Chery New Energy, Changan Automobile, GAC Group, Jiangling Motors, Lifan Auto, MIN AN Auto, Wanxiang Group, YUDO Auto, Chongqing Sokon Industrial Group, ZTE, National Electric Vehicle, LeSEE, NextEV, Chehejia, SINGULATO Motors, Ai Chi Yi Wei and WM Motor.

Sources are indicated in the table.

**Key point:** By April 2017, nine global OEMs had publicly announced their willingness to create or significantly widen their electric model offer over the next five to ten years. Several Chinese OEMs also announced very significant electric car production capacity scale-up plans.

Overall, accounting for the global OEM announcements and targets listed in Table 2, the electric car stock stemming from the OEM targets could range between 9 million and 20 million by 2020. Considering announcements to 2025 and applying growth rates based on the RTS to targets announced to 2020, the OEM announcements listed in Table 2 could lead to 40-70 million electric cars on the road by 2025.

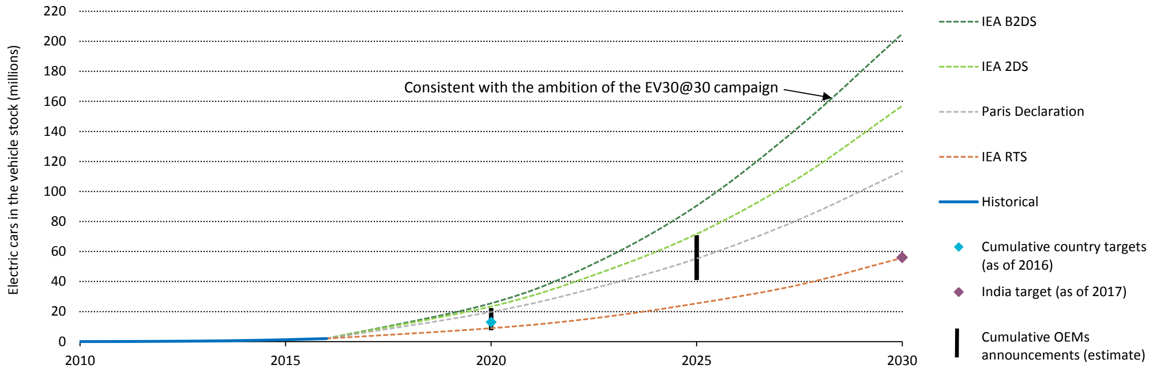
The level of ambition resulting from the OEM announcements assessed here shows a fairly good alignment with country targets to 2020. To 2025, the range estimated suggests that OEMs' ambitions lie within the range corresponding to the RTS and 2DS projections from the IEA, broadly matching the Paris Declaration. In order to see these ambitions materialise, EV (and

[19] This rate matches the indications currently available for the average capacity utilisation of Chinese auto manufacturing plants given the information available from CAAM (2017) and IHS (2017).

battery) production capacity needs to increase. The scale of this challenge can be illustrated by comparing the battery capacity additions needed against recent developments: attaining the mid-point of the estimated ranges for OEM announcements in 2025 would require the construction of roughly ten battery manufacturing facilities with the production capacity of the Tesla Gigafactory.[20]



**Figure 9 • Deployment scenarios for the stock of electric cars to 2030**




Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2017a), IHS Polk (2016), MarkLines (2017), ACEA (2017a, 2017b) and EEA (2017). Country targets in 2020 reflect the estimations made in EVI (2016a) and updates to date. India's target reflects a conservative interpretation of the announcement made by the government (PIB India, 2017): 50% of the PLDV stock of the country (in the B2DS) is electrified by 2030. The assessment methodology for OEM announcements included in Table 2 is discussed in the main text. Projections on the stock deployed according to the Paris Declaration are based on UNFCCC (2015a). Projections on the EV uptake in IEA scenarios were developed with the IEA Mobility Model, March 2017 version (IEA, 2017a).

**Key point:** The level of ambition resulting from the OEM announcements assessed shows a fairly good alignment with country targets to 2020. To 2025, the range estimated suggests that OEM ambitions lie between the range corresponding to the RTS and 2DS projections from the IEA, broadly matching the Paris Declaration.

The recent redefinition of the EVI ambition to reach a collective market share (in all modes except two-wheelers) of 30% by 2030 (as spelled out in the EV30@30 campaign), places the ambition of EVI countries in line with the B2DS,[21] provided that the carbon intensity of power generation declines rapidly (see Box 2 for insights on the $CO_2$ emissions reduction benefits stemming from a shift to electrified powertrains today and by 2030 while electric grids progressively decarbonise).

**Box 2 • Progress towards decarbonisation targets**

Electrifying road transportation has multiple benefits, including the reduction of emissions of local pollutants and noise and the promotion of energy security and decarbonisation through increased energy efficiency and diversification. If transport electrification goes hand-in-hand with the decarbonisation of the electricity supply, it will also be effective for significantly reducing GHG emissions. Figure 10 aims to provide a comparative assessment of the $CO_2$ intensities of electric vehicles, benchmarking BEVs and PHEVs against other powertrain technologies. It does so by looking at major global regions characterised by variable average car sizes and grid carbon intensities under different grid decarbonisation scenarios. The broad spectrum of options covered in Figure 10 provides a good basis to discuss the advantages and disadvantages of EVs in different contexts.

[20] This calculation is based on an annual 8 million EV production in 2025, equally shared between BEVs and PHEVs, one Gigafactory-type plant being able to deliver 0.5 million BEV batteries per year (Tesla, 2014).

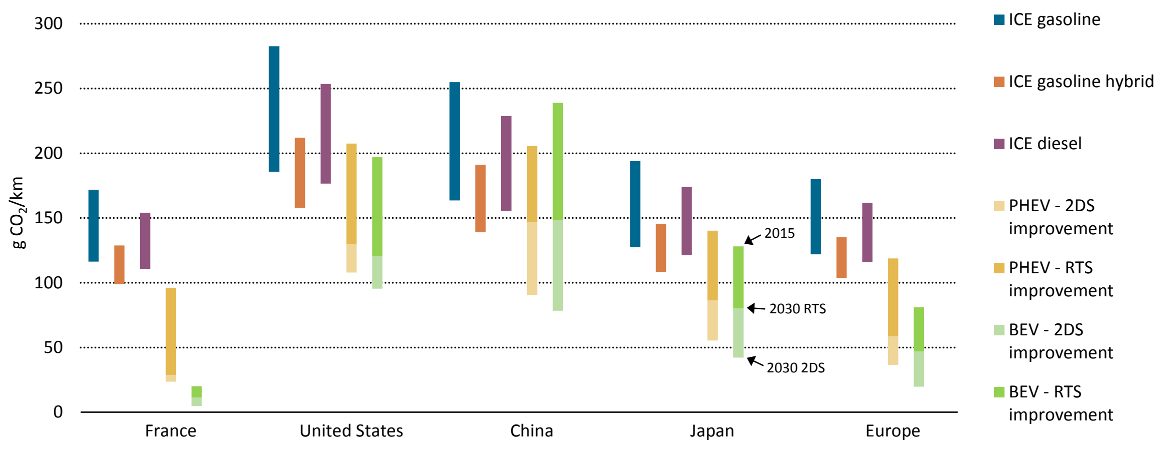
[21] The B2DS is consistent with a 25% EV market share (for all road modes excluding two-wheelers) by 2030 worldwide and about 30% in EVI countries. These same shares grow to 30% and are in the 35-40% range when looking at PLDVs only. In the 2DS, the corresponding global EV market share is 18% and close to 25% in EVI countries.



France can be used as an example of a country characterised, in 2015, by fuel efficient vehicles with a fairly low average power rating and a low-carbon grid thanks to the high share of nuclear electricity.[22] Under these circumstances, electric cars lead to emissions per km that are lower than any other powertrain technology at any point in time between now and 2030 in all of the IEA scenarios. In 2015, BEVs and PHEVs were already a lower-carbon option than ICEs and HEVs in the United States, Japan and Europe as a whole (considering the GHG emission intensity per kWh of the average European electricity generation mix). In China, the high carbon intensity of the current electricity production mix (still exceeding 700 g $CO_2$/kWh in 2015, one of the highest in the world at the national level) hampers the benefits of EVs in terms of GHG emission reductions. In 2015, HEVs in China were the only technology that could achieve on-road stock average emissions below the 200 g WTW $CO_2$/km threshold. With the 2015 GHG intensity of the Chinese grid, BEVs are more $CO_2$ intensive than HEVs and diesel cars. Under the same conditions, PHEVs are a better alternative to both ICEs and BEVs, but they are still worse than HEVs.

**Figure 10 • On-road well-to-wheel $CO_2$ emissions for PLDVs for various powertrain technologies by country or region: RTS and 2DS, 2015 to 2030**




Notes: The upper limit of each bar shows the well-to-wheel (WTW) $CO_2$ emissions estimated for each powertrain technology in 2015. The lower limit of the dark shading in each bar shows the WTW $CO_2$ emissions from the technology in 2030, assuming technology and grid decarbonisation improvements aligned with the RTS. The bottom of the light-shaded part of the bars shows the WTW $CO_2$ emissions in 2030, assuming technology and grid decarbonisation improvements aligned with the 2DS. Vehicle powertrain characteristics reflect the regional assumptions of IEA (2017a). PHEV $CO_2$ emissions are calculated on the basis of an electric driving rate of 30% of the total mileage in 2015 and an electric driving rate of 80% of the total mileage in 2030.

Source: IEA (2017a), IEA Mobility Model, March 2017 version.

**Key point:** In order to deliver significant GHG emission reductions, transport electrification needs to go hand-in-hand with the decarbonisation of power generation.

Prospects for 2030 account for improved fuel economy for conventional passenger cars compared with 2015 and 15 years of grid decarbonisation efforts. Under an RTS trajectory, BEVs and PHEVs offer lower-carbon solutions than ICEs and HEVs in all regions shown in Figure 10, except China. For China, a decarbonisation ambition coherent with the RTS (with a grid intensity at 533 g $CO_2$/km) would not be sufficient to ensure that BEVs and PHEVs perform better, from a GHG emissions perspective, than HEVs and diesel cars. This suggests that there is a strong imperative for China to increase its grid decarbonisation efforts if it wants to transition to electric mobility (as the country's current developments and ambitions suggest – these are largely driven by a pressing need to address urban air pollution) while meeting global climate targets. Only a rapid decarbonisation trajectory (Figure 10 shows results for the 2DS, but the B2DS carbon intensities for power generation would also qualify for this) would allow electric cars to break the 100 g $CO_2$/km (well-to-wheel) threshold in 2030 in the country. In the 2DS, BEVs would emit under 20 g $CO_2$/km in Europe, five times less than comparable ICE and HEV options available in 2030.

[22] A similar assessment could also be made for Brazil or Norway, for example. Both are characterised by similar average vehicle sizes as France and by a low GHG-intensive grid thanks to high shares of hydroelectricity.

Although this assessment accounts for the full fuel lifecycle emissions of different powertrains on a real drive basis, it does not provide a comparative assessment of the GHG impact of vehicle manufacturing for the different powertrain options. A study carried out in the Netherlands suggests that an electric car provides a $CO_2$ benefit on a lifecycle basis – including car manufacturing and recycling – compared to a gasoline car in nearly all cases. This is not the case only when the electric car is entirely powered by coal, the most $CO_2$-intensive electricity source (935 g $CO_2$/kWh). When less-GHG-intensive grids are taken into account – which is the case for most national grids at the global level – the GHG benefit of BEVs on a full lifecycle basis becomes sizeable: electric cars are 54% less $CO_2$ intensive with a 200 g $CO_2$/kWh grid intensity than their gasoline counterparts (Van Gijlswijk et al., 2014; Verbeek et al., 2015; Willemsen, 2016).



# Other modes

## *Low-speed electric vehicles*

Low-speed electric vehicles (LSEVs) are gaining relevance primarily in China, where they have emerged as a competitor to both electric vehicles and two-wheelers. LSEVs generally have a maximum speed of between 40 km/h and 70 km/h, have short ranges and, in some cases, use lead-acid batteries and basic motor technology. Estimates for LSEV sales in 2016 were between 1.2 million and 1.5 million, and the year-on-year growth rate since 2014 was close to 50% for the third consecutive year (Auto Sohu, 2016, 2017a, 2017b; CIIN, 2016; Daily Economic News, 2016 and Jiren, 2017). Since LSEVs started to develop after 2011 (EVI, 2016a), their current stock is likely to be close to 3-4 million units.

The main attractions of LSEVs are their low cost, small size, and the lack of regulations (for instance, they do not require a driving licence or insurance to operate). This is especially advantageous for low-income consumers who live in small or medium-sized cities, the elderly, and those in cities where the number of new licence plates is restricted. In China's Shandong province, the growing LSEV industry has also contributed significantly to job creation.[23]

The growing use of LSEVs has not materialised without concerns. The use of lead-acid batteries has had negative environmental effects, and the lack of regulations for LSEV manufacturers has led to poor safety performance. Traffic safety is also at stake. LSEVs struggle in large cities due to their poor acceleration and low top speeds. They are often used in bike lanes, and, since both the drivers and the LSEVs themselves do not require specific documentation to operate, are difficult to control. Lastly, LSEVs could jeopardise the market for electric cars, one of China's priorities for industrial policy development.

Legislation to regulate and standardise LSEVs is currently being discussed by the Chinese government (MIIT, 2016). According to the China Electrical Car Network (CNEV), some of the issues that will be addressed by regulations include battery types (lead-acid versus lithium-ion batteries), mandatory safety tests and vehicle dimensions (Yang, 2016). The high-level objective is to upgrade the LSEV fleet in circulation, regulate and standardise the vehicles and eliminate the LSEVs that do not comply with these standards.

## *Two-wheelers and three-wheelers*

China continued to dominate both new registrations and the global stock of electric two-wheelers in 2016, with estimates of sales that are in line with those reported in EVI (2016a) (roughly 26 million, according to the EVI data submission from China). Given the development of

[23] In Shandong province, more than 0.6 million LSEVs were sold in 2016, almost 50% of the national LSEV sales in China (Diandong, 2017).

two-wheeler sales over time and scrappage ages that should be reasonably close to eight to ten years, the vehicle stock should also be in the same magnitude of the values estimated for 2015, in the 200-230 million range. While data quality and collection remain an issue, it is evident that China is by far the global leader. The high growth rate in electric two-wheelers is partially due to the country's policies to limit air pollution hazards, such as its ban on gasoline-powered motorcycles, limits on the issuing of licences, and the division of lanes (Yang et al., 2014). Additionally, two-wheelers have reached cost parity with ICE models, making them affordable and attractive to consumers.



Further data collection is necessary to validate and compare more countries and rationalise information for international comparison. The few data points available suggest that the United Kingdom experienced a positive growth in the number of two-wheelers from 2015 to 2016.[24] Sweden also witnessed an increase in 2015 from 2014, but data were unavailable for 2016.

Three-wheelers, widespread in Asian countries and mainly known as *tuk-tuks*, are also attracting the attention of policy makers and are bound to become increasingly electrified. For example, the Thai government is planning to start electrifying its vehicle fleet by tackling *tuk-tuks* through a subsidy programme aimed at supporting the introduction of 100 of them by 2018. The policy goal is to fully replace the 22 000 *tuk-tuks* currently on the roads within five years (Thai Rath, 2016).

## *Electric buses*

The global battery-powered electric bus stock grew to about 345 000 vehicles in 2016, double the number in 2015. Despite potentially significant data classification issues, China emerges as the global leader in the electrification of buses. According to available statistics, the stock of electric buses in China reached 343 500 units in 2016, and included about 300 000 BEVs. Within China, Shenzhen is one of the most ambitious cities globally regarding the electrification and modernisation of its bus systems. In 2016, hundreds of electric buses were already in operation. Shenzhen has also set the goal of having a 100% electric bus fleet in 2017 (Hall et al., 2017).[25]

Europe accounted for 1 273 vehicles in the global electric bus stock in 2016, while the United States accounted for 200. The European electric bus stock more than doubled from 2015, suggesting that the market is moving beyond the demonstration phase into commercial development. As an example, the public transport operator of the city of Paris opened its first electric bus line in 2016. Meanwhile, the same operator is getting ready for widespread electrification and plans to replace 80% of its existing bus fleet with electric buses by 2025 – this translates to roughly 4 000 electric buses being deployed in the next eight years (RATP, 2017). In the United States, the electric bus manufacturer Proterra doubled its sales in 2016 compared to 2015 but has only sold 380 vehicles since the company's founding in 2004 (Proterra, 2017).

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[24] In the United Kingdom, electric two-wheelers are eligible for a GBP 1 500 (USD 2 000) grant under certain conditions (Gov.uk, 2017b).

[25] In addition to buses, Shenzhen also uses minibuses on several routes, combined with on-demand electric bus services, (potentially upgraded to new routes) to connect the last mile between homes and regular bus and metro stations, with the aim of maximising the efficiency and effectiveness of its bus services.

# Electric vehicle supply equipment

Charging infrastructure, whether at home, at work or at public locations, is indispensable for operating EVs. Analysis looking at early EV market developments shows that the availability of chargers emerged as one of the key factors for contributing to the market penetration of EVs. Ensuring the availability of chargers is also essential for enabling the diversification of the transport fuel mix and catalysing its transition towards clean energy.

This section focuses on the electric charging infrastructure needed to supply electric vehicles. It looks primarily at EVSE deployments for electric cars. This is for two reasons:

- The importance, in terms of the number of vehicles, of electric cars for the growth prospects of electric mobility: the number of electric cars deployed in all the scenarios for the next 15 years is comparable to the magnitude projected for two- and three-wheelers but is significantly larger than the values imputed for buses, other public transport vehicles and trucks, given that these modes constitute a fairly small fraction of the total vehicle stock.
- The power requirements needed for the energy supply of electric cars clearly exceed those needed to charge smaller vehicles, such as two-wheelers and, therefore, are more likely to require the deployment of novel components of the electricity production, transmission and distribution infrastructure.

The section is structured as follows:

- First, it looks at the nature of the EVSE needed by electric cars and briefly summarises the existing standards and types of chargers in the main global EV markets: China, Europe, Japan, and North and Central America (including Canada, Mexico and the United States).
- Second, it provides a numerical overview of the status of EVSE deployment.
- Third, it considers existing policy support mechanisms, looking specifically at the deployment of charging infrastructure in cities and the role of local authorities.
- Finally, it presents prospects for EVSE developments that could match the scenarios on electric car uptake discussed previously, building on the information available on electric cars and charging infrastructure discussed in this report.

## Standards and types of chargers

Charging electric vehicles requires the use of cables, connectors and communication protocols between the vehicles and the EVSE, as well as the EVSE-grid communication, i.e. the communication between the EVSE and the distribution system operator (DSO). The EVSE suitable for electric cars has three main characteristics:

- **level**, describing the power output of an EVSE outlet
- **type**, referring to the socket and connector being used for charging
- **mode**, which describes the communication protocol between the vehicle and the charger.

International standardisation bodies and other associations define these characteristics through standards. Standards may focus on just one of the characteristics or a combination of them. Key standardisation entities involved in the development of these standards include the International Organization for Standardization (ISO); the International Electrotechnical Commission (IEC); the Society of Automotive Engineers (SAE) of the United States; and the Standardization Administration of China (SAC), which issues Chinese national standards (GuoBiao, GB).

CHAdeMO, an association of vehicle manufacturers and utilities, also became active in this area in 2009 through the development of a DC quick-charging standard, which was started in Japan and uses a specific type of connector and communication protocol. In 2016, the association announced an amendment to the current protocol, enabling charging up to 150 kW and the development of technical analyses for fast chargers with a higher power rating (350 kW) (CHAdeMO, 2016). Currently, several mass-produced electric cars are equipped with connecting devices enabling the use of CHAdeMO chargers,[26] and adaptors are available for most models using different connectors (CHAdeMO, 2012).

CharIN is a similar association with a broader scope in terms of membership and representation across the automotive sector. It was established in 2015 with the aim of promoting a global charging standard (CharIN, 2015) and now promotes the combined charging system (CCS) and the combo connectors used in Europe and the United States, suggesting a vision for future developments. This approach enables fast charging at 200 kW and developments are now targeting 350 kW (CharIN, 2017a).

In addition to these standard-setting bodies and associations, Tesla has been using its own standard to support all levels and modes of charging through the same connector type. The exception is now Europe, where Tesla needs to comply with the mandate regarding interoperability objectives to use specific standards for sockets and connectors for normal (Level 2) and high-power (Level 3) recharging points (EC, 2014). In 2016, Tesla also became a member of CharIN.

**Table 3 • Overview of the level (power output) and type (socket and connector) of EVSE used in China, Europe, Japan and the United States**

<table>
<tr><th rowspan="2">Classification in use here</th><th rowspan="2">Level</th><th rowspan="2">Current</th><th rowspan="2">Power</th><th colspan="4">Type</th></tr>
<tr><th>China</th><th>Europe</th><th>Japan</th><th>North America</th></tr>
<tr><td></td><td>Level 1</td><td>AC</td><td>≤ 3.7 kW</td><td colspan="3">Devices installed in private households, the primary purpose of which is not recharging electric vehicles</td><td>SAE J1772 Type 1</td></tr>
<tr><td rowspan="2">Slow chargers</td><td>Level 2</td><td>AC</td><td>> 3.7 kW and ≤ 22 kW</td><td>GB/T 20234 AC</td><td>IEC 62196 Type 2</td><td>SAE J1772 Type 1</td><td>SAE J1772 Type 1</td></tr>
<tr><td>Level 2</td><td>AC</td><td>≤ 22 kW</td><td colspan="4">Tesla connector</td></tr>
<tr><td rowspan="3">Fast chargers</td><td>Level 3</td><td>AC, triphase</td><td>> 22 kW and ≤ 43.5 kW</td><td></td><td>IEC 62196 Type 2</td><td></td><td>SAE J3068 (under development)</td></tr>
<tr><td>Level 3</td><td>DC</td><td>Currently < 200 kW</td><td>GB/T 20234 DC</td><td>CCS Combo 2 Connector (IEC 62196 Type 2 & DC)</td><td>CHAdeMO</td><td>CCS Combo 1 Connector (SAE J1772 Type 1 & DC)</td></tr>
<tr><td>Level 3</td><td>DC</td><td>Currently < 150 kW</td><td colspan="4">Tesla and CHAdeMO connectors</td></tr>
</table>

Sources: IEA elaboration based on AFDC (2017), Bohn (2011), CHAdeMO (2012), CharIN (2017a), CharIN (2017b), EC (2014), Electric Vehicle Institute (2017), HK EMSD ( 2015) and State Grid Corporation of China (2013).

**Key point:** Various sockets and connectors are in use across the main global regions. Two main combined charging systems (CCSs) were recently developed to standardise the connections. They are the current standards adopted in Europe and the United States.

Table 3 provides an overview of the level (power output) and type (socket and connector) of EVSE used in China, Europe, Japan and the United States. Overall, it is important to highlight

[26] Manufacturers including Peugeot and Mitsubishi, Renault-Nissan and Hyundai Kia use CHAdeMO connectors and protocols for fast charging, regardless of the market.

connectors for two main CCSs, which have been recently developed to minimise differences and are gaining relevance. They are currently suitable for the Level 2 and 3 standards adopted in Europe and the United States. These standards, coupled with the HomePlug PHY communication protocol and the global standard for communication between charging stations and electric cars, are emerging as the most interesting recent developments towards a global charging solution.[27]

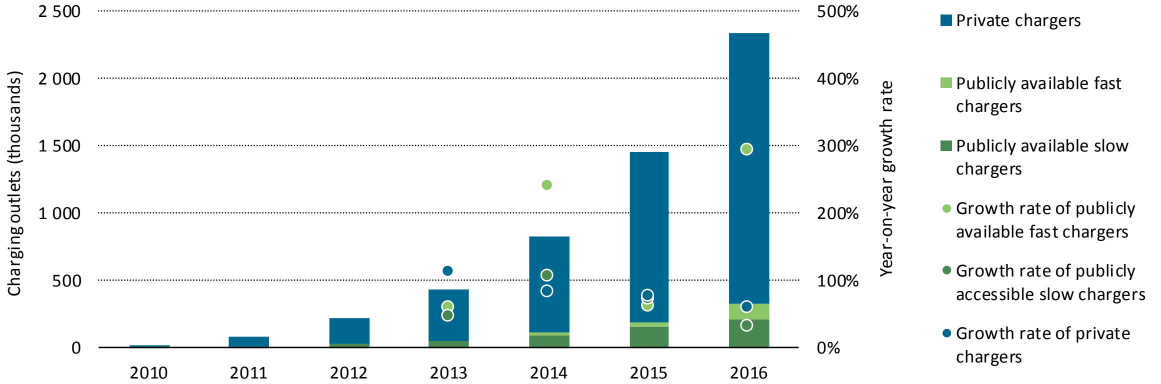


To date, there are few standardised protocols for EVSE-grid communication, but efforts to develop them have started. Elaad's work on the Open Smart Charging Protocol is amongst the most interesting developments in this area (Montes Portela et al., 2015).

## Historical developments

Similarly to the global electric car stock, global EVSE outlets surpassed 2 million in 2016.[28] Electric cars still outnumber public charging stations by more than six to one, indicating that most drivers rely primarily on private charging stations (Figure 11).[29]

**Figure 11 • Global EVSE outlets, 2010-16**




Note: Private chargers in this figure are estimated assuming that each electric car is coupled with a private charger.

Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2017a).

**Key point:** Publicly accessible infrastructure is growing to support the emerging EV market, especially publicly accessible fast chargers.

The growth of publicly accessible chargers accompanies the increase in the number of electric cars on the road: the growth rate in the number of publicly accessible chargers in 2016 (72%) was higher, but of similar magnitude, to that of the electric car stock growth in the same year (60%). The higher rate of growth for chargers than electric cars is consistent with the need to deploy

[27] The HomePlug PHY was developed as an industry-led initiative comprising 60 member companies to create specifications for using power lines for reliable broadband home networking and smart grid applications. Recently updated to version Green PHY, it has been specified as the base technology for data exchange in the global standard for communication between charging stations and electric cars developed by ISO/IEC 15118 (Homeplug, 2012; ISO, 2015).

[28] The discussion on EVSE deployment developed here refers to two main categories of chargers, defined as slow and fast chargers, corresponding to Levels 2 and 3 in Table 3.

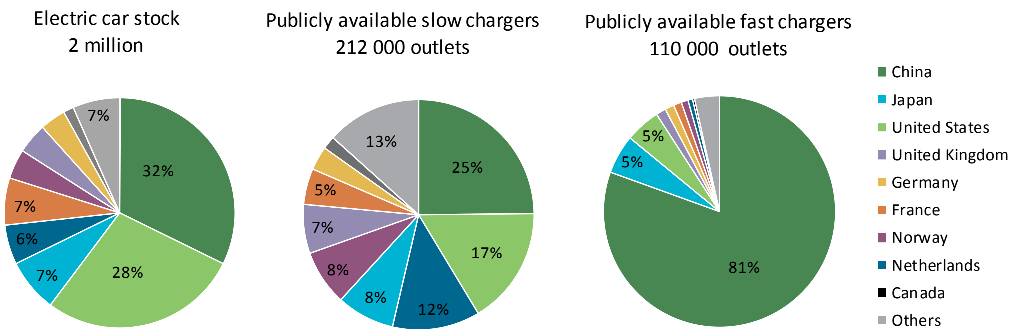
[29] As in EVI (2016a), this assessment still relies on the assumption that each EV on the road is coupled with a private charger. Statistics regarding the installation of private chargers are often inexistent or incomplete at an aggregated level as it is the choice of each individual to install a private charger at home when buying an EV. Since the installation of a home charger is usually supported by the OEM for each EV sold (by direct installation by the OEM, for example), it is estimated that, to date, each EV has access to a dedicated private charger. EV owners that do not have the possibility of installing a home charger (because they do not have a dedicated parking spot if they live in urban centres, for example), and must, therefore, rely on publicly accessible charging, also have the option to rely on a growing number of workplace chargers. These workplace chargers are also not accounted for in the statistics regarding publicly accessible outlets.

chargers as a prerequisite for EV adoption and the nascent nature of most of the electric car markets.[30]

Publicly accessible EVSE growth was primarily driven by the rapid increase in the number of fast chargers, largely attributable to China, where fast chargers grew sevenfold to nearly 90 thousand units.[31] Even when China is not considered, the growth rate for publicly accessible fast chargers in 2016 was still greater than publicly available slow chargers.



**Figure 12 • Electric car stock and publicly available EVSE outlets, by country and type of charger, 2016**




Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2017a).

**Key point:** Electric cars still outnumber public charging stations by more than six to one, indicating that most drivers rely primarily on private charging stations. Publicly available EVSE shares are not evenly distributed across markets. This is consistent with the early stage of electric car deployment.

Figure 12 shows the regional distribution of electric cars (left-hand chart), publicly accessible slow chargers (centre chart) and fast chargers (right-hand chart). Figure 12 indicates that the shares of publicly available EVSE are not evenly distributed across markets, reflecting large variations in EV/EVSE ratios across counties. This is consistent with the early stage of EV deployment in most markets. In the case of fast chargers, the large global share for China could be the result of the rapid growth of electric buses (significantly larger than in any global region so far) and significant uncertainty about the share of fast chargers actually dedicated to bus services. Japan, where 50-kW fast chargers were deployed early in order to address range anxiety (i.e. the fear that a vehicle has insufficient energy stored on board to reach the next available recharging point or its destination), but where EV sales have not experienced recent, significant year-on-year growth, also has high shares of fast chargers per EV compared with other countries.

# EVSE policy support

## *Overview*

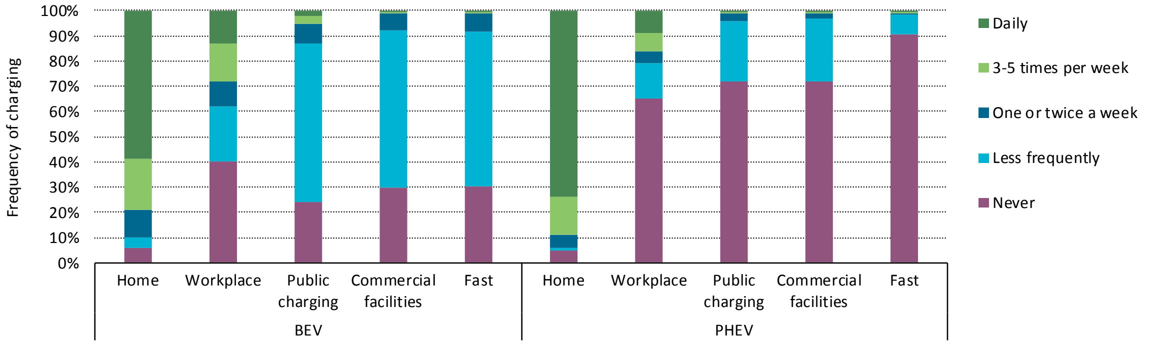
Evidence from Norwegian BEV and PHEV users (Norway is the country with the highest electric car penetration) suggests that electric car charging does not match refuelling habits for internal combustion engines even when electrified powertrains substitute for ICEs of a similar category (Figure 15). Unlike ICE drivers, electric car owners most frequently charge their vehicles at home

[30] The case of Norway, which has a larger EV market and stock shares than any other country, suggests that markets that have already deployed a sizeable share of EVs in their stock tend to require a lower average number of chargers per EV, reflecting higher capacity utilisation rates for EVSE.

[31] By the end of 2016, China accounted for 44% of publicly accessible chargers in the world and 80% of the world's publicly accessible fast chargers. It is unclear whether a part of these fast chargers could be dedicated to electric buses, the numbers of which are also increasing quickly in the country.

or at work, relying on slow chargers. The third most frequent charging choice is publicly available slow chargers, followed by chargers located in commercial facilities (charging at a destination). Fast charging is not used frequently, and it primarily takes the form of planned stops for long-distance trips (Figenbaum and Kolbenstvedt, 2016).

**Figure 13 • Charging habits for a sample of Norwegian electric car users, 2016**




Source: IEA elaboration based on results from Figenbaum and Kolbenstvedt (2016).

**Key point:** electric car owners charge their vehicles most frequently at home or at work. The third most frequent charging option is publicly accessible slow charging. Fast charging is not frequently used.

The importance of the availability of charging infrastructure on the prospects for electric car market growth calls for continued support for EVSE deployment. The need to minimise deployment costs suggests that the deployment of charging infrastructure should be tailored to the evolution of the electric car stock growth. Successful EVSE deployment strategies also need to match consumer preferences. EV charging could also have a sizeable impact on the capacity required by the grid at certain times and locations, with consequences for the adequacy and quality of the power supply, risks of cost increases for consumers and negative feedback on transport electrification prospects. EVSE deployment needs to be conceived in a way that handles these risks while taking advantage of the options available for mitigating these impacts.

The discussion that follows attempts to outline policy recommendations taking into account these constraints. It does so by looking at measures needed to support EVSE deployment at different administrative levels. First, it identifies topics that need to be addressed by national or cross-national actions. Second, it looks at the role of local administrations, providing examples of good practices from the existing policy context. Finally, it elaborates on the challenges posed by EVSE deployment for the power system and discusses the options for dealing with them.

## *National and supra-national policy frameworks*

National and international policy frameworks aiming to support the deployment of EVSE are well suited to achieving significant progress. Key instruments available to national and supranational institutions for this purpose include standards to ensure the interoperability of EVSE nationwide and across country borders, definitions of EVSE deployment targets, financial incentives, regulations (including building codes) and permits. Energy companies, utilities and distribution system operators (DSOs) also deploy electric vehicle charging. Box 3 provides a brief overview of their initiatives in this context.

### Standards ensuring the interoperability of EVSE nationwide and across country borders

Given the importance for drivers of operating vehicles across different jurisdictions, access and the interoperability of charging infrastructure and payment methods are key enablers for the deployment of electric cars. The provision of an integrated and interoperable EVSE network is especially important in regions characterised by a multinational structure, like the European Union.

The case of the CCSs coupled with the HomePlug PHY communication protocol is suitable for the Level 2 and 3 in Europe – mandated through the European Directive on the Deployment of Alternative Fuels Infrastructure (EC, 2014) – and is well suited to evolve in the direction of a success story for overcoming physical barriers to interoperability.

A number of web-based applications are emerging to facilitate the access, use and payment of EVSE. The added value of these services is the possibility to overcome the significant barriers to interoperability posed by the local focus of charging infrastructure, typically relying on specific identification systems (e.g. based on radio frequency identification), contracts and payment methods. Examples of platforms allowing drivers to unlock charging stations with their navigation system or an app and to pay for the electricity based on agreements established with charging providers include Ladenetz, Hubject and Plugsurfing (Kafyeke, 2017; Hall and Lutsey, 2017).

### EVSE deployment targets

Defining EVSE deployment targets also helps speed up policy action. The advantage of setting targets is the ability to focus on the development of instruments for meeting them and moving beyond the need to decide upon their ambition. EVI (2016a) provides an overview of EVSE deployment targets. A summary is reported here:

- China aims to deploy, by 2020, 4.3 million private EVSE outlets, 0.5 million public chargers for cars and 850 intercity quick-charge stations, among other targets for buses and taxis.
- The EU Directive on the Deployment of Alternative Fuels Infrastructure (EC, 2014) required EU member countries to define electric charging point targets for 2020 by November 2016.[32] France has stated its ambition to deploy 7 million charging outlets by 2030.
- In 2016, Korea upgraded its former target for deploying countrywide, publicly accessible fast chargers by 2020 from 1 400 to 3 000, with the aim of making all parts of the country accessible with an electric vehicle (MoE, 2016).

### Financial incentives, fiscal advantages and other forms of monetary incentives

National legislative frameworks are also important for providing financial incentives, fiscal advantages and other forms of monetary incentives for individuals, businesses and local authorities willing to invest in the installation of EVSE. Several EVI countries have a range of measures falling in this category:

- In China, the central government supports municipalities deploying public charging infrastructure by subsidising the construction of charging stations.
- In France, financial incentives can take the form of a tax credit equivalent to 30% of a home charger or subsidies for the installation of residential or workplace chargers (MEEM, 2016a).
- In the Netherlands, the Green Deal has resulted in a governmental contribution for the joint deployment of publicly accessible EVSE with municipalities and a third party. This is

[32] Despite this, not all EU member states submitted their plans, and an assessment summarising the results of those already submitted is not yet available.

accompanied by a tax incentive for businesses investing in EVSE deployment (Munnix, 2017).

- Norway provides EVSE public funding for fast-charging stations every 50 km (on average) on main roads and contributes to deployment incentives for public chargers.
- Sweden offers financial support for the development of charging infrastructure. In 2015, the funding amounted to SEK 130 million.
- In the United Kingdom, individuals receive GBP 500 (USD 650) for the installation of a dedicated home charger for an electric car, and businesses are entitled to grants of GBP 300 (USD 400) per socket to fund charge points for fleets and/or employees (Gov.uk, 2017a) and receive tax breaks for investment on large EVSE deployment (Gov.uk, 2016a). Local authorities also receive refunds to install roadside charge points in residential areas.
- In the United States, most EVSE support takes place at the state level. For example, the state of Colorado provides grants of up to 80% of the costs for an EVSE unit and installation (Hodge, 2017).



### Regulations and permits

Policy areas where national or international action can be especially effective are the integration of EVSE charging infrastructure in building codes and the adaptation of property and tenancy laws to simplify EVSE deployment. To date, an increasing number of countries has provided specific policies to include EVSE infrastructure in building codes, tenancy and property regulations:

- In France, recent legislation mandated that 50-75% of parking bays in any new or renovated residential building must be pre-installed with conduits that allow the easy installation of EVSE ranging between 7 kW and 22 kW. In commercial buildings, 5-10% of parking bays must have conduits suitable for installing EVSE with a power rating of at least 22 kW (Legifrance, 2016). The European Commission included similar provisions in a proposal aiming to revise the EU Directive on the Energy Performance of Buildings (EC, 2016a).
- In France, Spain, Portugal and the United States (California), steps have been taken to adapt property laws to simplify and accelerate the process of approval procedures for electric car owners to deploy (private) EVSE infrastructure, notably in rented and/or owned multi-unit dwellings, including in parking garages (Legifrance, 2014; BOE, 2009; Diario da Republica, 2010; WXY Architecture, 2012).

### Direct investments and public-private partnerships

National governments are also well placed to enable nationwide EVSE deployment, either in the form of direct investment or through public-private partnerships (PPPs). One example is allowing private parties to construct fast-charging networks on highways.

- The company Fastned has already built more than 60 fast-charging stations in the Netherlands. It will be building 14 more in Germany (Fastned, 2017) and others in the United Kingdom (Munnix, 2017).
- In the United States, the states of Washington, Oregon and California together organised an extensive network of DC fast-charging stations, the West Coast Electric Highway, which connects the three states through stations along major roadways located every 40-80 km. This project is structured as a PPP whereby the costs are shared by the public

sector, the private sector and users, with significant shares of seed funding from the public sector (West Coast Green Highway, 2017).

**Box 3 • Industry initiatives on EVSE deployment**

Energy companies, utilities and distribution system operators (DSOs) deploy electric vehicle charging networks to diversify their business, capitalising on the access to the power distribution infrastructure and unique expertise in the electrical system, enabling them to anticipate or enable opportunities likely to emerge from demand-side management. Having direct access to the customers they serve for stationary electricity applications, they are well positioned to deploy private chargers at home (where they also compete with OEMs) or at the workplace.

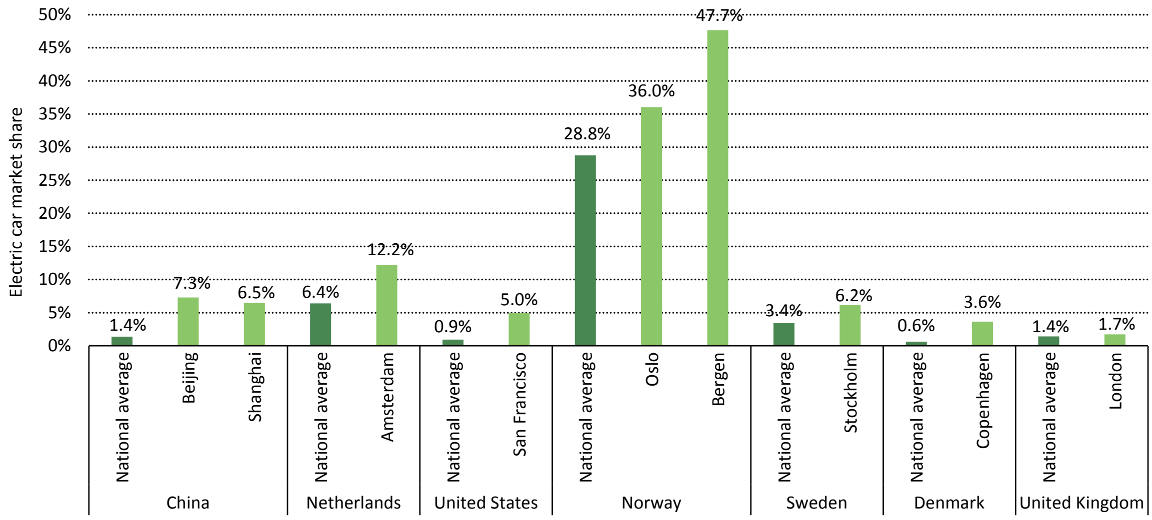
Large energy companies have also been responsible for a significant portion of all public charging stations. In Germany, power companies, including RWE, Vattenfall, E.ON and EnBW, account for 35% of all public charging stations (Hall and Lutsey, 2017). Utilities and DSOs have also collaborated to open nationwide networks through partnerships. Examples include the Elaad Foundation in the Netherlands, pulling together seven network operators (Hall and Lutsey, 2017; Elaad, 2017), and Clever, a company owned by major Scandinavian energy companies and aiming to stablish Europe's first ultra-fast charging network for electric vehicles (Hall and Lutsey, 2017; Clever, 2017). Local municipal utilities have also entered the EVSE market. In China, the State Grid Corporation of China and China Southern Power Grid have together opened more than 27 000 charging stations and more than 800 electric vehicle battery-swapping stations for buses (Hall and Lutsey, 2017). In North America, utility investment in public electric vehicle charging networks is still in its early phases but is showing signs of growing quickly.

OEMs have also taken the initiative to deploy charging services. Tesla's supercharger network consists of more than 5 000 fast-charging points at dedicated locations along major highways. The company plans in 2017 to double its destination charging network of more than 9 000 connectors, which are located in public destinations, such as hotels, resorts and restaurants (Tesla, 2017b, 2017c; EC, 2016b). BMW, Daimler, Ford and Volkswagen recently announced a plan to develop a joint European network of fast chargers for electric cars along major highways in Europe (Daimler, 2016b).

## *Policy needs best addressed by cities and local administrations*

Cities have been at the forefront of stimulating EV deployment and are important players in helping to accelerate the transition to electric driving. Leading EV cities have shown that, as a result of dedicated local policies complementing national EV policy schemes, they can create a favourable environment for EV use and reduce consumer barriers. Nearly a third of global electric car sales took place in just 14 cities in 2015 (Hall et al. 2017), and major global urban centres often achieve higher electric car market shares compared to their country averages (Figure 16). Air quality issues are one of the main drivers for cities to stimulate EVs (IEA, 2016).

**Figure 14 • Market share of electric cars in leading EV countries compared to high-performing EV cities, 2016**




Notes: The data for specific cities refers to electric cars that are registered within the municipality. This does not exclude the possibility that the electric car is used in other areas.

Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2017a), IHS Polk (2016), MarkLines (2017), ACEA (2017a, 2017b) and EEA (2017). City shares were defined based on Johnsen (2017), Denver (2017), Gov.uk (2017c), Isbrand (2017), Kasche (2017), Munnix (2017), SIC (2017) and Visser (2017).

**Key point:** Major urban centres often achieve higher electric car market shares compared to their country averages.

Cities can have a leadership role in developing and testing innovative policy actions before more widespread adoption (Hall et al., 2017). By testing and demonstrating best-practice EV support policies, cities can not only act as models for other cities that seek to accelerate their transitions to electric driving but also provide an example for a wide application (e.g. at the national or global level) of best practices, helping to improve the cost efficiency of the policy development process. This includes a unique role to play in supporting EVSE deployment within urban areas in a way that best adapts to the characteristics of the urban mobility and geography of each city.

Parking ordinances and zoning actions are instruments that have a strict relationship with urban networks. Local authorities have a clear lead in the development of these networks and in making decisions on how they should be used. Cities are best placed to manage EVSE deployment in terms of geographical location and ensure adequate charging opportunities in urban areas.

- In Paris, the municipality has mandated that all electric cars are allowed to use the chargers of its Autolib electric car-sharing programme, with the additional benefits of free parking and dedicated parking spots (Hall et al., 2017).
- The metropolitan area of Amsterdam has adopted one of the most interesting policy strategies, which involves zoning actions via a demand-based approach for deploying its EVSE network (Vertelman and Bardok, 2016). This approach comprises the deployment of public charging infrastructure only upon the identification of user-based demand (citizens can sign up with the municipality to have a charger installed near their home when purchasing an EV), and only if there are no private or off-street alternative solutions. This innovative initiative allows the deployment of public charging infrastructure in an optimised way by installing new, publicly accessible charging outlets only when coupled with new EVs circulating in the area. This is likely to maximise use and, thus, optimise investment. Additionally, it supports an EVSE deployment strategy aligned with consumer preferences of prioritising private charging (at home and the

workplace), followed by publicly accessible slow charging when one of the former options is not available (Figure 15). The slow-charging feature of the scheme (7kW to 11kW) does not pose unmanageable risks for the distribution grid capacity. Such a scheme also contributes to lower EV adoption barriers for customers that do not have access to private parking and thus private charging.



With the exception of standardisation, which is clearly best addressed at the national and international levels, and measures strongly related with urban road networks, all other categories identified for national and international policy action also have relevance for cities and local administrations. The following list includes a selection of examples of city-level initiatives taken in each of the support action areas outlined in this report that have contributed to improving the EVSE offering in urban centres and have thus supported EV adoption:

- **Targets**

  Some cities have developed their own targets for direct investment or for the number of public charging points to be installed. For example, the municipality of Shanghai (China) aims to build 210 000 charging points by 2020 (Hall et al., 2017). Vancouver (Canada) has also been incorporating EVSE into its long-term goals for buildings, transportation and economic planning (WXY Architecture, 2012).

- **Financial incentives**

  Cities can also provide financial incentives for installing charging points. The municipality of Utrecht in the Netherlands offers a EUR 500 subsidy per private charging point and a subsidy of EUR 1 500 for a semi-public charging point (Hall et al., 2017). Other types of incentives have taken the form of attractive charging prices. For example, the municipality of Beijing has set an upper limit on the fee that needs to be paid to use public charging electricity infrastructure (net of the electricity price) at 15% of the price of gasoline (Beijing.gov.cn, 2015).

- **Building codes**

  In Vancouver, the city council has taken advantage of its unique ability among Canadian cities to modify its building code to require that each new, single-family dwelling is capable of supporting Level 2 charging infrastructure, and that 20% of the parking stalls in multifamily buildings (three or more dwelling units) are equipped with wire conduits for accommodating EVSE outlets. In doing so, Vancouver has become the first North American city to require EVSE connection capability in all new building developments (WXY Architecture, 2012).

  The recent EV Readiness Ordinance adopted in San Francisco also includes provisions to facilitate electric car charging in buildings, requiring, for new construction or major building renovation, the installation of Level 2 chargers in 10% of the parking spaces and conduits enabling additional installations in another 10%. The ordinance also requires the capacity to handle the simultaneous charging of vehicles in 20% of the parking spaces, and enabling the use of charging management systems to scale up and provide charging for up to 100% of the spaces (CLGEEP, 2017).

  Chinese cities have similar (and stronger) requirements: Beijing, Shanghai and Chongqing, among other cities, require 100% charging pre-equipment (CEC, 2016).

- **Direct EVSE deployment**

  Direct EVSE deployment is carried out, for example, through EVSE procurement contracts with charge point suppliers. An example of such direct investment is the case of Oslo, where the municipality has built two large parking garages dedicated to electric cars (Hall et al., 2017).

- **Public-private partnerships**

  Business relationships funded and operated through partnerships between the public sector and one or more private companies could be effective for raising additional finance in an environment of budgetary restrictions (EC, 2016b). One interesting example of synergy between the public sector and private operators is the case of Source London, a citywide electric-vehicle charge point network. Source London was started by Transport For London (the integrated transport authority for London) and is now managed by a private operator, which currently provides more than 850 charge points across London and plans to install another 4 500 by 2018 (Source London, 2017).



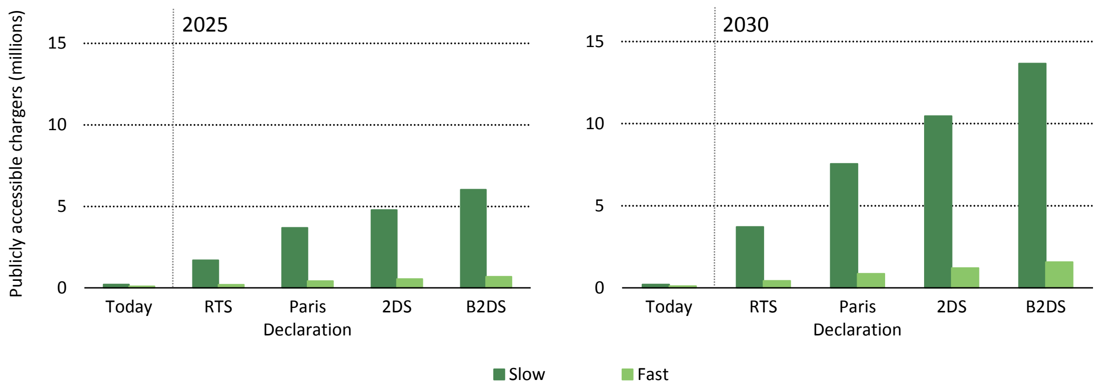
*EVI City Casebook: 50 Big Ideas Shaping the Future of Electric Mobility* provides an overview of other examples of other initiatives undertaken by cities to support EVs, including actions regarding EVSE deployment (EVI, 2014).

## Prospects for future EVSE deployment

Estimates for EVSE deployment targets corresponding to the main scenarios on EV deployment are summarised in Figure 13.

The number of EVSE outlets that need to be installed in the next 15 years depends on the electric car deployment scenario. Publicly available EVSE outlets need to grow by a factor that ranges between 8 in the RTS and 25 in the B2DS by 2025, amounting to between 4 million and 14 million outlets globally in 2030. Projections for fast chargers suggest that EVI markets will need to see the deployment of 0.1 million additional outlets by 2025 in the RTS and 0.6 million in the B2DS. Extending the period to 2030 corresponds with 0.2 million outlets in the RTS and 0.7 million outlets in the B2DS.

**Figure 15 • EVSE outlets by country and by type of charger, 2016**



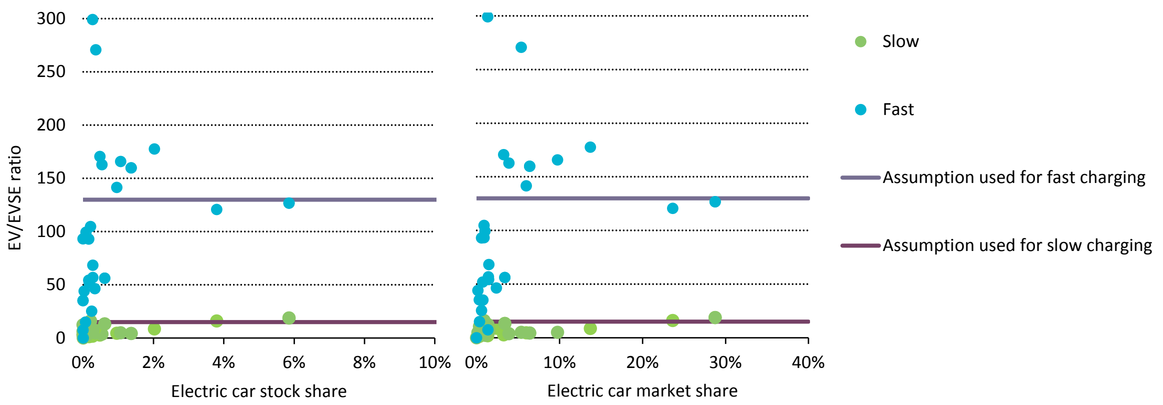

Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2017a), IHS Polk (2016), MarkLines (2017), ACEA (2017a, 2017b) and EEA (2017) and projections on EV uptake developed with the IEA Mobility Model, March 2017 version (IEA, 2017a).

**Key point:** EVSE outlets need to accompany EV deployment. Depending on the scenario considered, EVSE outlets will range between 1 million and 7 million in 2025 and double that in 2030.

These results were calculated on the basis of the electric car deployment projections outlined earlier and assumptions on the EV/EVSE ratios (by charger level). The assumptions were derived from the overview of the historical development of the EV/EVSE ratios, illustrated in Figure 14, where the EV/EVSE ratios for each country are plotted against both the electric car market share and the electric car stock share. Despite a wide variability at low electric car market and stock shares, the EV/EVSE ratios have been assumed here to converge towards 15 electric cars per publicly accessible slow charger and 130 electric cars per fast charger.

**Figure 16 • EVSE outlets by country and by type of charger, 2016**






Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2017a), IHS Polk (2016), MarkLines (2017), ACEA (2017a, 2017b) and EEA (2017).

**Key point:** Plotting the EV/EVSE ratios against both electric car market share and electric car stock share and giving priority to markets with higher electric car deployment suggests that, despite a wide variability at low electric car market and stock shares, EV/EVSE ratios could converge towards 15 electric cars per publicly accessible slow charger and 130 electric cars per fast charger.

Due to the wide variability of results for low electric car market and stock penetration, the average EV/EVSE ratios considered for the estimates of the EVSE requirements for 2025 and 2030 were heavily weighted towards the values observed in countries with comparatively high electric car market and stock shares, primarily Norway and the Netherlands. This rationale is also supported by the observation that the EV/EVSE values for Norway and the Netherlands tend to be on the high end of the range observed for all EVI countries. The EV/EVSE ratio used here is similar to the value of ten vehicles per charger indicated in the EU Directive on the Deployment of Alternative Fuels Infrastructure (EC, 2014). The choice to give greater weight to markets with larger market shares of electric cars is consistent with the idea that scale effects become more relevant when market shares grow, helping optimise the use of charging infrastructure in comparison with early market deployment phases.[33]

Compared with the EVSE deployment scenarios suggested in the *Global EV Outlook 2016* (EVI, 2016a), the current estimates are similar to the lower EVSE range estimates. This is because the more developed electric car markets weighted in this analysis have high EV/EVSE ratios compared to the range of values taken into account in the previous *Global EV Outlook* edition.

[33] Given the variability and gaps between the current EV/EVSE ratios in each individual country and the choice to focus on the EV/EVSE ratios of Norway and the Netherlands to assess future developments, the estimations developed here are more likely to be accurate within the 2025-30 timeframe, when electric car market and stock shares are projected to grow. The accuracy of this assessment is lower in earlier years as the estimates are more strongly influenced by the current status of the EV/EVSE ratio. Projections on EVSE development also depend on the technologies and charging modes used. The assumptions made here do not account for major developments in this respect and implicitly consider that consumer behaviour will broadly reflect current preferences. Monitoring these developments will be important for refining this approach over time.

# Challenges and opportunities for the power sector

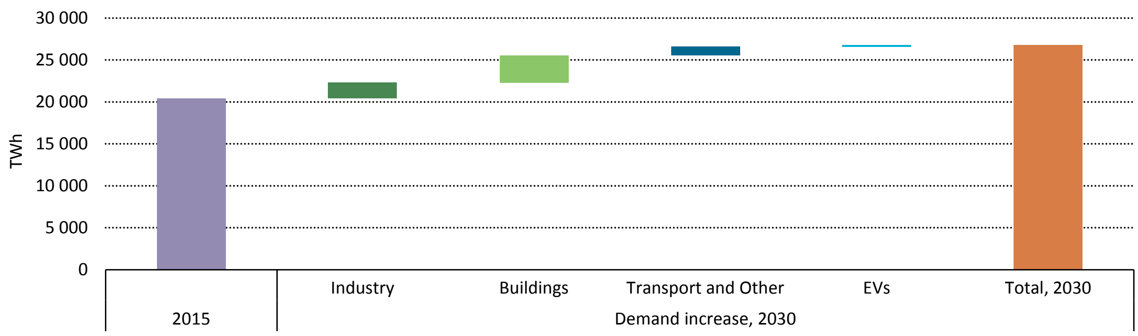
## Impact of EVs on the power system



Electricity systems need to ensure both system adequacy and quality of service. The extent to which higher shares of EVs and their demand for charging will impact electricity networks will depend highly on the technologies and charging modes used. The bulk of electric car charging is expected to occur at homes and businesses or in public charging facilities. Rising EV penetration is thus likely to have an impact on low-voltage distribution grids in residential or commercial areas first. In addition, EVs, in contrast with other loads on distribution networks, are not stationary. A greater understanding of EV charging patterns and technologies will thus be necessary to ensure their appropriate integration into distribution grids.

When new loads are incorporated into the grid, this translates into guaranteeing both sufficient energy and capacity are available on demand. IEA analysis shows the additional energy demand from EV loads is sizeable but largely manageable (IEA, 2017b). In the IEA 2DS, the additional generation required to meet the EV and PHEV demand amounts to 1.5% of the total electricity demand by 2030 – which would represent only 6% of the increase in demand due to new loads from electrification in industry and the residential and commercial sectors (Figure 17).

**Figure 17 • Impact of electric car deployment on global electricity demand, 2DS**




Source: IEA (2017b).

**Key point:** The additional energy demand from electric car loads is sizeable but largely manageable in comparison with total energy use and additional loads arising from the industry, other transport and buildings sectors

Depending on the electric car usage patterns, i.e. when, where and how much power is drawn from what type of charging infrastructure, higher shares of electric cars could have a sizeable impact on the capacity required at certain times and locations, with consequences for both adequacy and quality at different levels:

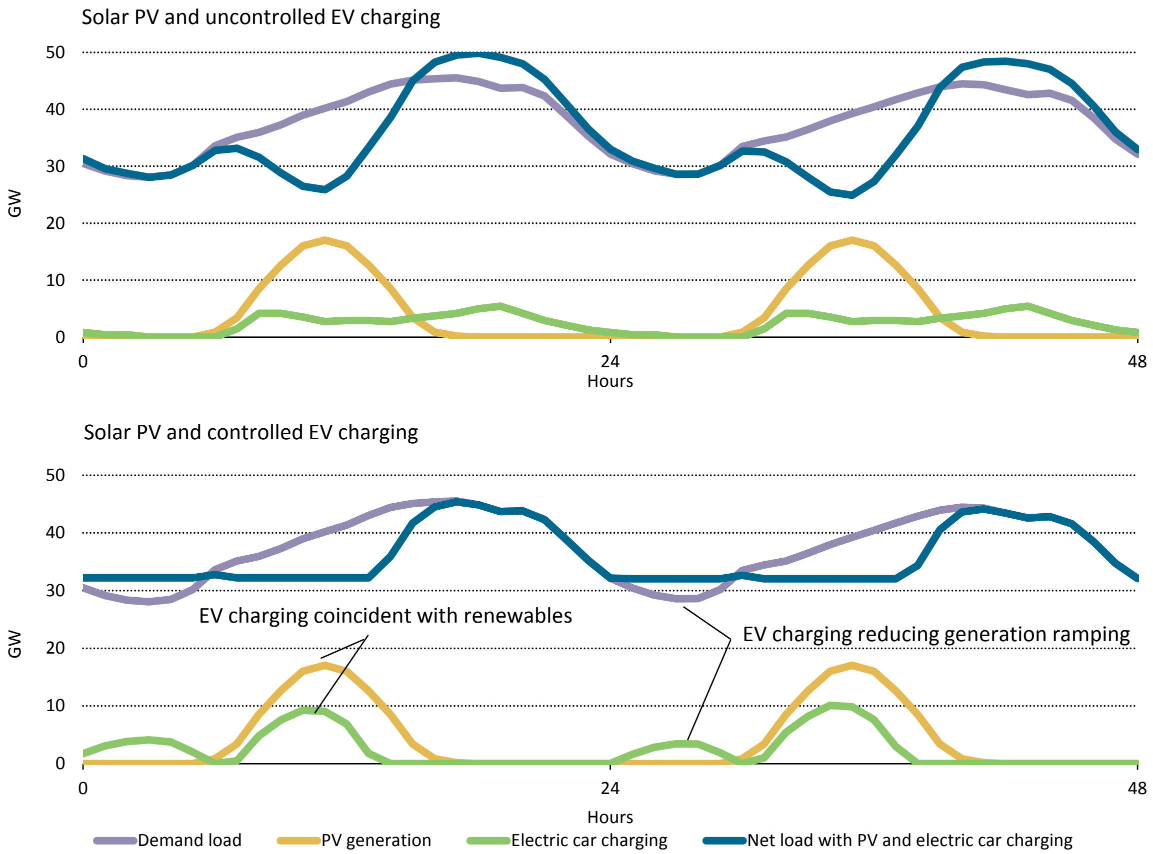
- at the generation/wholesale market level, where high demand and scarce capacity could increase prices
- at the transmission/system operator level, where stress on the system during peak times requires more system services, such as frequency control, and the need to maintain reserve power capacity
- at the distribution level, where the overloading of power lines and transformers and voltage drops could occur.

The impact of EV charging will be felt first at local hotspots on distribution grids before the other two levels are affected. In such local situations, network overloads can result in the accelerated ageing of grid infrastructure and eventually cause service interruptions, which could require investments for upgrading lines and transformers.



To place these concepts in context, Figure 18 shows the additional residential load from electric cars during a typical day under the B2DS in the European Union in 2030, comparing the impact of standard usage patterns with those that could be enabled through price and control signals without impacting travel demand according to current best knowledge. According to this assessment, unmanaged charging would result in an increase in peak power draw of roughly one-third.

**Figure 18 • Local demand profile and electric car charging in the European Union on a typical day, B2DS, 2030**




Sources: IEA (2017b).

**Key point:** In a scenario with high electric car market penetration, unmanaged charging could result in a sizeable increase (over 30%) in peak power draw.

## Mitigating the potential impacts of EV charging

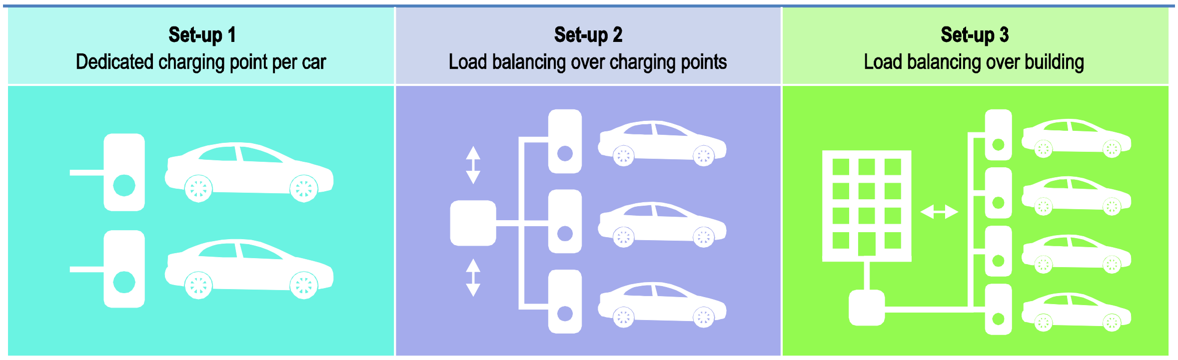
Three options are particularly relevant for mitigating the negative impacts of electric car charging. One option is the buildout of charging infrastructure itself and deploying it both at locations and with technologies that minimise any negative impacts. At homes and businesses, connecting local charging points generally requires some form of connection from the low-voltage grid, and the additional load could require subscribing to a higher power capacity tariff and/or reinforcement of the network at the point of connection. It is thus critically important to install charging points in areas where both the projected impact is low and the utilisation throughout the day is expected to be high. An early example of such robust planning of EVSE is in the Netherlands, where the installation of charging points is tied to residential areas where electric car owners request parking permits.

A second option is through incentivising end users to maximise self-consumption through solar systems installed on consumers' homes combined with the available storage and recharging infrastructure. As utilities transition to distributed energy, such business models could be deployed as an integrated service combining energy efficiency, distributed energy resources and the minimisation of EV charging costs – and, on the utility side, provide system benefits by reducing the impact of the charging profiles seen by the grid. The combination of reducing EV battery costs, increased EV uptake and spillovers into stationary battery technology will require regulators to monitor and balance the adoption by consumers of such distributed electric car charging options with networked charging.



Charging infrastructure can also be scaled up in phases that follow the growth of electric car uptake (Figure 19). Careful planning for this could bring economic advantages as well as advantages for grid stability. The first set-up phase of EVSE deployment, which can be identified as the present phase of most urban areas, can be handled with a few initial charging points. In the second phase, as electric cars become more numerous, a typical parking garage (or a suburban road) is needed to distribute the available power between a number of charging points. In this second phase, challenges start to arise as the number of charging points must be limited to the available power in the building (or neighbourhood). In the third phase, in which there is a large demand for charging from electric cars, the available power of the entire building needs to be distributed between the apartments in the building (or the network of dwellings in the neighbourhood) and the charging points.

**Figure 19 • Development of charging infrastructure in buildings with rising numbers of electric cars**




Source: IEA elaboration based on emerging commercial concepts such as www.zaptec.com

**Key point:** Charging infrastructure can be scaled up in phases that follow the growth of the electric car market.

As EV penetration increases, such options could deliver lower costs for both charging infrastructure owners/operators and distribution grids. The question is thus whether the existing cost signals and regulations are sufficient to drive end users and owners/operators of charging stations to drive enough efficiency and flexibility at the system level. In multifamily dwellings, public charging stations and parking lots, for instance, higher capacities can be expected. The higher the charging capacity, the higher the need to manage charging – and yet, given the higher demand for it, users are likely to be less amenable to changing their charging profiles. If the demand-side operator (DSO) needs to reinforce lines and transformers, plus bear its share of the cost of the home grid connections due to regulations, it will then seek to pass on costs to consumers through the tariff system, exacerbating the issue without increasing flexibility.

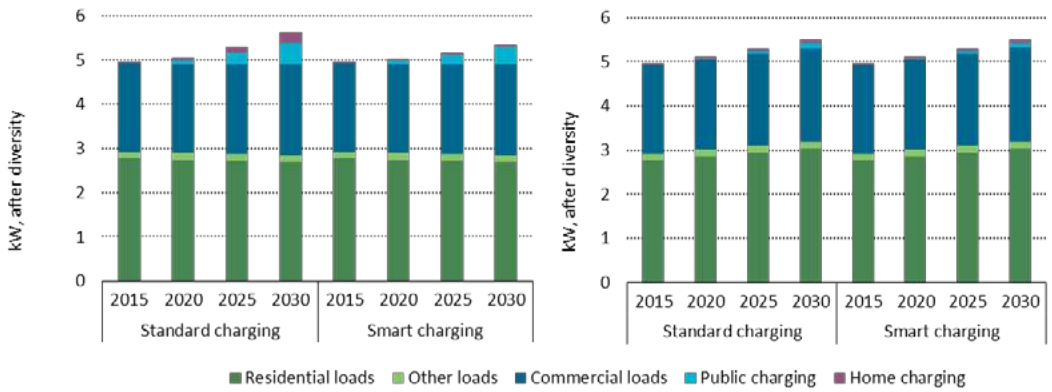
Some form of additional regulation, generally in the form of digitally enabled, smart charging of electric cars, will be necessary. To enable smart charging, regulators and policy makers will have to enable business models that deliver some combination of price signals, control signals and aggregation enabled by data analytics and controls for a large numbers of users.



Price signals incentivise flexible electric car loads to respond to time-of-use, dynamic hourly prices. Control signals can be enabled by grid operators at the EVSE level or within vehicles. Either of these would require an underlying information and communications technology (ICT) infrastructure for communicating between charging points and back-end systems and for allowing operators to send requests to increase or reduce the power draw at certain times.

The savings from allowing delayed charging can be significant at the system level. An assessment of the realisable economic potential from flexible smart charging in the 2DS reveals nearly 350 GW of flexibility available from the deployment of nearly 600 million BEVs and PHEVs by 2030, resulting in an estimated USD 180 billion in generation, transmission and distribution capacity (Figure 20).

**Figure 20 • Impact of electric car deployment on a generic local grid in the European Union, B2DS (left) and 2DS (right)**




Source: IEA (2017b).

**Key point:** The savings from allowing delayed charging at an early stage of electric car deployment could allow for increased hosting capacity for loads from additional electric cars.

Providing price signals to consumers could deliver some of these savings by incentivising consumers to reduce peak loads. However, price signals in energy markets do not adequately reflect the condition of the network, particularly in distribution networks and particularly at times when the network is heavily constrained. As electric car penetration increases, aggregators to allow for delayed charging will be needed. Signals given to charging stations will have to consider the generation and grid constraints as well as enable customers to benefit from price opportunities. Such opportunities require aggregating large numbers of individual loads through analytics and local area control.

While aggregators could operate in wholesale markets, they could also trade with the local network operator to provide system services. Given that the impact of EVs is likely to emerge at the local level, such services should be evaluated and implemented early in their deployment. Meanwhile, who should provide these services is a question that is tied to specific systems and regulatory designs – options include public utilities, third parties and e-mobility service providers. These could provide, on a contractual basis, delayed charging of large numbers of ICT-enabled charging points with constraints and charging profiles set by the DSO, which could in turn provide increased hosting capacity to service providers without having to invest in upgrading the network.

Finally, as electric car penetration increases, charging infrastructure will require common standards and interoperable solutions between charging stations, distribution networks and the electric cars themselves. Interoperability is necessary both on the physical-electricity-network side but equally at the ICT interface, where information will need to flow efficiently across the range of stakeholders along the value chain of the charging service. At the network level, information includes grid conditions, available capacities and the instantaneous generation mix. At the end-user level, this would include information on battery usage and condition, state of charge and status. Interoperability and common standards are necessary to ensure compatibility and efficient communication and, fundamentally, to enable EVs as flexible roaming platforms where consumers can be aggregated as they drive and charge in different local distribution networks.

# Conclusion



With record-high new electric car registrations in 2016 (over 750 thousand sales worldwide), the transition to electric road transport technologies that began only a decade ago is gaining momentum and holds promise for a low-emission future, provided that such dynamism can be sustained over the coming decades. As the global stock of electric cars surpasses 2 million units, a number of countries are coming forward as global leaders. Norway had the highest electric car market share globally (29%) in 2016. China experienced an extremely rapid market growth, from 100 thousand units in circulation in 2014 to 650 thousand units two years later. The provision of private and publicly accessible charging infrastructure has accompanied the growth of the electric car stock. In 2016, the number of publicly accessible charging points reached 320 000 units globally, representing a 72% growth since 2015. These successes are driven by the multiple benefits EVs can bring to governments and citizens: energy security (thanks to the energy efficient nature of electric mobility and reduced dependence to oil), urban air quality, noise mitigation and greenhouse gas reductions.

Governments and local authorities are implementing policies aimed at reaping the benefits of EVs. The tools currently available for policy makers include, among others, purchase subsidies, measures supporting EVSE deployment, fuel economy standards, ZEV mandates and access restrictions. RD&D and mass production are also delivering rapid cost declines and increases in energy density. Signs of continuing improvements in technologies currently being researched confirm that these trends will continue and that they will further improve performance and narrow the cost competitiveness gap between electric and ICE vehicles.

In the next 10 to 20 years the electric car market will likely transition from early deployment to mass market adoption. Assessments of country targets, OEM announcements and scenarios on electric car deployment seem to confirm these positive signals; indicating that the electric car stock may range between 9 million and 20 million by 2020 and between 40 million and 70 million by 2025.

As the number of EVs increases, charging could have a sizeable impact on the capacity required by the grid at certain times and locations, with consequences for the adequacy and quality of the power supply, risks of cost increases for consumers and the potential for negative feedback on transport electrification prospects. EVSE deployment needs to be conceived in a way that manages these risks while taking advantage of the options available for mitigating these impacts. The potential contribution of EVs to the decarbonisation of the global economy, among a variety of other benefits, is substantial. EVs are well suited to promote synergies with variable renewables. If charging practices strengthen demand-side management opportunities, EVs could allow a greater integration of these energy sources in the power generation mix. Large-scale electric car charging and demand response will require the joint optimisation of the timing and duration of recharging events, the modulation of power delivered by charging outlets (defining the speed of charge) and may involve a reliance on vehicle-to-grid solutions. For fast chargers, managing power demand is also likely to require the deployment and use of stationary storage at the local or grid level.

Moving beyond early market developments for electric cars will require policy adjustments. As battery pack costs decrease, electric vehicles will become increasingly cost competitive. The need for vehicle purchase incentives will diminish, and subsidies for electric cars will not be economically sustainable with large sales volumes. As the share of electric vehicles sold increases, revenues collected from conventional fuel taxes will also shrink. The decline will be largest in the countries with the highest fuel taxes, such as the European Union and Japan. Ensuring that infrastructure funded by these revenues (e.g. public transport infrastructure, road networks, and alternative fuel and low-carbon infrastructures) continues to be developed will require a transition in the way these revenues are collected. Applying taxes based on vehicle distance travelled rather than fuel consumed is likely to be the most suitable alternative (IEA, 2017b).

Growing EV sales will also stimulate the demand for commodities needed for battery manufacturing, such as lithium, cobalt and other materials required by future battery technologies. This will require understanding the distribution and accessibility of these resources, and, as in the case of other strategic commodities, may come with risks. Monitoring the price and availability of these resources, but also minimising the environmental impacts of their extraction and processing, will be necessary to put the EV market on an economically and environmentally sustainable trajectory. Battery reuse and material recycling will become increasingly important in this context. Policies will need to steer the use of batteries in secondary applications (such as stationary energy storage), and their end-of-life treatment. Policies will also be needed to deal with issues relating to battery ownership, transport and recycling requirements.

# Statistical annex



This section provides electric car and EVSE time series data for the 39 countries covered in the scope of this report, i.e. EVI members, countries falling under the scope of activity of the European Alternative Fuels Observatory and countries that reported data to the EVI (Figure 4). These data were those used for the graphs and the discussions in this report.

In each of the tables below, "others" comprises Austria, Belgium, Bulgaria, Croatia, Cyprus,[34] the Czech Republic, Denmark, Estonia, Finland, Greece, Hungary, Iceland, Italy, Ireland, Latvia, Lichtenstein, Lithuania, Luxemburg, Malta, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Switzerland and Turkey.

The main sources of information used in this report include submissions from EVI members, statistics and indicators available from the European Alternative Fuels Observatory (EAFO, 2017a) for European countries that are not members of the EVI (Figure 4), data extracted from commercial databases (IHS Polk, 2016; MarkLines, 2017) and information released by relevant stakeholders (ACEA, 2017a, 2017b; EEA, 2017).

[34] 1. Footnote by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus issue". 2. Footnote by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

# Electric car stock

### Table 4 • Electric car stock (BEV and PHEV) by country, 2005-16 (thousands)

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canada | | | | | | | 0.52 | 2.54 | 5.66 | 10.73 | 17.69 | 29.27 |
| China | | | | | 0.48 | 1.91 | 6.98 | 16.88 | 32.22 | 105.39 | 312.77 | 648.77 |
| France | 0.01 | 0.01 | 0.01 | 0.01 | 0.12 | 0.30 | 3.03 | 9.29 | 18.91 | 31.54 | 54.49 | 84.00 |
| Germany | 0.02 | 0.02 | 0.02 | 0.09 | 0.10 | 0.25 | 1.89 | 5.26 | 12.19 | 24.93 | 48.12 | 72.73 |
| India | | | | 0.37 | 0.53 | 0.88 | 1.33 | 2.76 | 2.95 | 3.35 | 4.35 | 4.80 |
| Japan | | | | | 1.08 | 3.52 | 16.14 | 40.58 | 69.46 | 101.74 | 126.40 | 151.25 |
| Korea | | | | | | 0.06 | 0.34 | 0.85 | 1.45 | 2.76 | 5.95 | 11.21 |
| Netherlands | | | | 0.01 | 0.15 | 0.27 | 1.14 | 6.26 | 28.67 | 43.76 | 87.53 | 112.01 |
| Norway | | | 0.01 | 0.26 | 0.40 | 3.35 | 5.38 | 9.89 | 20.37 | 44.21 | 84.18 | 133.26 |
| Sweden | | | | | | | 0.18 | 1.11 | 2.66 | 7.32 | 15.91 | 29.33 |
| United Kingdom | 0.22 | 0.55 | 1.00 | 1.22 | 1.40 | 1.68 | 2.89 | 5.59 | 9.34 | 24.08 | 48.51 | 86.42 |
| United States | 1.12 | 1.12 | 1.12 | 2.58 | 2.58 | 3.77 | 21.50 | 74.74 | 171.44 | 290.22 | 404.09 | 563.71 |
| Others | | | | | 0.64 | 0.83 | 3.25 | 6.90 | 12.76 | 25.35 | 52.63 | 87.48 |
| Total | 1.37 | 1.69 | 2.15 | 4.54 | 7.47 | 16.81 | 64.58 | 182.64 | 388.07 | 715.39 | 1 262.61 | 2 014.22 |

### Table 5 • Battery electric cars, stock by country, 2005-16 (thousands)

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canada | | | | | | | 0.22 | 0.84 | 2.48 | 5.31 | 9.69 | 14.91 |
| China | | | | | 0.48 | 1.57 | 6.32 | 15.96 | 30.57 | 79.48 | 226.19 | 483.19 |
| France | 0.01 | 0.01 | 0.01 | 0.01 | 0.12 | 0.30 | 2.93 | 8.60 | 17.38 | 27.94 | 45.21 | 66.97 |
| Germany | 0.02 | 0.02 | 0.02 | 0.09 | 0.10 | 0.25 | 1.65 | 3.86 | 9.18 | 17.52 | 29.60 | 40.92 |
| India | | | | 0.37 | 0.53 | 0.88 | 1.33 | 2.76 | 2.95 | 3.35 | 4.35 | 4.80 |
| Japan | | | | | 1.08 | 3.52 | 16.13 | 29.60 | 44.35 | 60.46 | 70.93 | 86.39 |
| Korea | | | | | | 0.06 | 0.34 | 0.85 | 1.45 | 2.76 | 5.67 | 10.77 |
| Netherlands | | | | 0.01 | 0.15 | 0.27 | 1.12 | 1.91 | 4.16 | 6.83 | 9.37 | 13.11 |
| Norway | | | 0.01 | 0.26 | 0.40 | 3.35 | 5.38 | 9.55 | 19.68 | 41.80 | 72.04 | 98.88 |
| Sweden | | | | | | | 0.18 | 0.45 | 0.88 | 2.12 | 5.08 | 8.03 |
| United Kingdom | 0.22 | 0.55 | 1.00 | 1.22 | 1.40 | 1.65 | 2.87 | 4.57 | 7.25 | 14.06 | 20.95 | 31.46 |
| United States | 1.12 | 1.12 | 1.12 | 2.58 | 2.58 | 3.77 | 13.52 | 28.17 | 75.86 | 139.28 | 210.33 | 297.06 |
| Others | | | | | 0.64 | 0.80 | 3.17 | 5.83 | 10.60 | 19.43 | 36.20 | 52.41 |
| Total | 1.37 | 1.69 | 2.15 | 4.54 | 7.47 | 16.42 | 55.16 | 112.94 | 226.78 | 420.33 | 745.61 | 1 208.90 |

### Table 6 • Plug-in hybrid electric cars, stock by country, 2005-16 (thousands)

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canada | | | | | | | 0.30 | 1.70 | 3.18 | 5.42 | 8.00 | 14.36 |
| China | | | | | | 0.34 | 0.66 | 0.92 | 1.65 | 25.92 | 86.58 | 165.58 |
| France | | | | | | | 0.10 | 0.70 | 1.53 | 3.60 | 9.28 | 17.03 |
| Germany | | | | | | | 0.24 | 1.40 | 3.02 | 7.41 | 18.52 | 31.81 |
| India | | | | | | | | | | | | |
| Japan | | | | | | | 0.02 | 10.98 | 25.11 | 41.28 | 55.47 | 64.86 |
| Korea | | | | | | | | | | | 0.27 | 0.44 |
| Netherlands | | | | | | | 0.02 | 4.35 | 24.51 | 36.94 | 78.16 | 98.90 |
| Norway | | | | | | | | 0.34 | 0.69 | 2.41 | 12.14 | 34.38 |
| Sweden | | | | | | | | 0.66 | 1.78 | 5.21 | 10.83 | 21.29 |
| United Kingdom | | | | | | 0.02 | 0.03 | 1.02 | 2.09 | 10.02 | 27.55 | 54.96 |
| United States | | | | | | | 7.98 | 46.57 | 95.58 | 150.94 | 193.77 | 266.65 |
| Others | | | | | | 0.02 | 0.08 | 1.07 | 2.16 | 5.92 | 16.43 | 35.07 |
| Total | | | | | | 0.39 | 9.42 | 69.70 | 161.29 | 295.06 | 517.00 | 805.32 |

# Electric cars: New registrations

**Table 7 • Electric cars (BEV and PHEV), new registrations by country, 2005-16 (thousands)**

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canada | | | | | | | 0.52 | 2.02 | 3.12 | 5.07 | 6.96 | 11.58 |
| China | | | | | 0.48 | 1.43 | 5.07 | 9.90 | 15.34 | 73.17 | 207.38 | 336.00 |
| France | 0.01 | | | 0.00 | 0.10 | 0.19 | 2.73 | 6.26 | 9.62 | 12.64 | 22.95 | 29.51 |
| Germany | 0.02 | | | 0.07 | 0.02 | 0.14 | 1.65 | 3.37 | 6.93 | 12.74 | 23.19 | 24.61 |
| India | | | | 0.37 | 0.16 | 0.35 | 0.45 | 1.43 | 0.19 | 0.41 | 1.00 | 0.45 |
| Japan | | | | | 1.08 | 2.44 | 12.62 | 24.44 | 28.88 | 32.29 | 24.65 | 24.85 |
| Korea | | | | | | 0.06 | 0.27 | 0.51 | 0.60 | 1.31 | 3.19 | 5.26 |
| Netherlands | | | | 0.01 | 0.03 | 0.12 | 0.88 | 5.12 | 22.42 | 15.09 | 43.77 | 24.48 |
| Norway | | | 0.01 | 0.24 | 0.15 | 0.39 | 1.84 | 4.51 | 8.52 | 19.76 | 35.61 | 50.18 |
| Sweden | | | | | | 0.00 | 0.18 | 0.93 | 1.55 | 4.67 | 8.59 | 13.42 |
| United Kingdom | 0.22 | 0.32 | 0.45 | 0.22 | 0.18 | 0.28 | 1.22 | 2.69 | 3.75 | 14.74 | 29.34 | 37.91 |
| United States | 1.12 | | | 1.47 | | 1.19 | 17.73 | 53.24 | 96.70 | 118.78 | 113.87 | 159.62 |
| Others | 0.53 | | | 0.08 | 0.03 | 0.18 | 2.43 | 3.64 | 6.05 | 12.77 | 26.62 | 35.31 |
| Total | 1.89 | 0.32 | 0.46 | 2.46 | 2.22 | 6.78 | 47.58 | 118.06 | 203.66 | 323.42 | 547.12 | 753.17 |

**Table 8 • Battery electric cars, new registrations by country, 2005-16 (thousands)**

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canada | | | | | | | 0.22 | 0.62 | 1.64 | 2.83 | 4.38 | 5.22 |
| China | | | | | 0.48 | 1.09 | 4.75 | 9.64 | 14.61 | 48.91 | 146.72 | 257.00 |
| France | 0.01 | | | 0.00 | 0.10 | 0.19 | 2.63 | 5.66 | 8.78 | 10.57 | 17.27 | 21.76 |
| Germany | 0.02 | | | 0.07 | 0.02 | 0.14 | 1.40 | 2.21 | 5.31 | 8.35 | 12.08 | 11.32 |
| India | | | | 0.37 | 0.16 | 0.35 | 0.45 | 1.43 | 0.19 | 0.41 | 1.00 | 0.45 |
| Japan | | | | | 1.08 | 2.44 | 12.61 | 13.47 | 14.76 | 16.11 | 10.47 | 15.46 |
| Korea | | | | | | 0.06 | 0.27 | 0.51 | 0.60 | 1.31 | 2.92 | 5.10 |
| Netherlands | | | | 0.01 | 0.03 | 0.12 | 0.86 | 0.79 | 2.25 | 2.66 | 2.54 | 3.74 |
| Norway | | | 0.01 | 0.24 | 0.15 | 0.39 | 1.84 | 4.18 | 8.20 | 18.09 | 27.79 | 29.52 |
| Sweden | | | | | | 0.00 | 0.18 | 0.27 | 0.43 | 1.24 | 2.96 | 2.95 |
| United Kingdom | 0.22 | 0.32 | 0.45 | 0.22 | 0.18 | 0.26 | 1.21 | 1.71 | 2.68 | 6.81 | 10.10 | 10.51 |
| United States | 1.12 | | | 1.47 | | 1.19 | 9.75 | 14.65 | 47.69 | 63.42 | 71.04 | 86.73 |
| Others | 0.53 | | | 0.08 | 0.03 | 0.16 | 2.38 | 2.65 | 4.96 | 9.00 | 16.11 | 16.67 |
| Total | 1.89 | 0.32 | 0.46 | 2.46 | 2.22 | 6.39 | 38.55 | 57.78 | 112.10 | 189.69 | 325.38 | 466.43 |

**Table 9 • Plug-in hybrid electric cars, new registrations by country, 2005-16 (thousands)**

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canada | | | | | | | 0.30 | 1.40 | 1.48 | 2.24 | 2.58 | 6.36 |
| China | | | | | | 0.34 | 0.32 | 0.26 | 0.73 | 24.27 | 60.66 | 79.00 |
| France | | | | | | | 0.10 | 0.60 | 0.83 | 2.07 | 5.68 | 7.75 |
| Germany | | | | | | | 0.24 | 1.16 | 1.62 | 4.39 | 11.11 | 13.29 |
| India | | | | | | | | | | | | |
| Japan | | | | | | | 0.02 | 10.97 | 14.12 | 16.18 | 14.19 | 9.39 |
| Korea | | | | | | | | | | | 0.27 | 0.16 |
| Netherlands | | | | | | | 0.02 | 4.33 | 20.16 | 12.43 | 41.23 | 20.74 |
| Norway | | | | | | | | 0.33 | 0.32 | 1.68 | 7.82 | 20.66 |
| Sweden | | | | | | | | 0.66 | 1.12 | 3.43 | 5.63 | 10.46 |
| United Kingdom | | | | | | 0.02 | 0.01 | 0.99 | 1.07 | 7.93 | 19.24 | 27.40 |
| United States | | | | | | | 7.98 | 38.59 | 49.01 | 55.36 | 42.83 | 72.89 |
| Others | | | | | | 0.02 | 0.06 | 0.99 | 1.09 | 3.76 | 10.51 | 18.64 |
| Total | | | | | | 0.38 | 9.03 | 60.28 | 91.56 | 133.73 | 221.74 | 286.75 |

# Electric cars: Market share

**Table 10 • Electric cars (battery electric and plug-in hybrid), market share by country, 2005-16**

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canada | | | | | | | | 0.15% | 0.20% | 0.29% | 0.39% | 0.59% |
| China | | | | | | 0.01% | 0.04% | 0.06% | 0.09% | 0.38% | 0.99% | 1.37% |
| France | | | | | | 0.01% | 0.13% | 0.34% | 0.55% | 0.72% | 1.22% | 1.46% |
| Germany | | | | | | 0.00% | 0.05% | 0.11% | 0.23% | 0.42% | 0.72% | 0.73% |
| India | | | | 0.02% | 0.01% | 0.01% | 0.02% | 0.05% | 0.01% | 0.02% | 0.04% | 0.02% |
| Japan | | | | | 0.03% | 0.06% | 0.35% | 0.53% | 0.63% | 0.68% | 0.58% | 0.59% |
| Korea | | | | | | | 0.02% | 0.04% | 0.05% | 0.09% | 0.21% | 0.34% |
| Netherlands | | | | | 0.01% | 0.02% | 0.16% | 1.02% | 5.38% | 3.89% | 9.74% | 6.39% |
| Norway | | | 0.01% | 0.22% | 0.15% | 0.31% | 1.33% | 3.27% | 6.00% | 13.71% | 23.63% | 28.76% |
| Sweden | | | | | | 0.00% | 0.05% | 0.31% | 0.53% | 1.44% | 2.37% | 3.41% |
| United Kingdom | 0.01% | 0.01% | 0.02% | 0.01% | 0.01% | 0.01% | 0.06% | 0.13% | 0.17% | 0.60% | 1.11% | 1.41% |
| United States | 0.01% | | | 0.01% | | 0.01% | 0.17% | 0.44% | 0.75% | 0.74% | 0.67% | 0.91% |
| Others | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.04% | 0.06% | 0.10% | 0.21% | 0.38% | 0.52% |
| Total | 0.00% | 0.00% | 0.00% | 0.01% | 0.01% | 0.01% | 0.10% | 0.23% | 0.38% | 0.54% | 0.85% | 1.10% |

Note: The total market share is calculated on the basis of the total market size of all the countries covered in this report.

# EVSE

## Table 11 • Publicly accessible slow charger stock by country, 2005-16 (number of units)

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canada | | | | | | | | 722 | 1 172 | 2 266 | 3 361 | 3 900 |
| China | | | | | | | | | | 21 000 | 46 657 | 52 778 |
| France | | | | | | | | 800 | 1 700 | 1 700 | 10 122 | 14 612 |
| Germany | | | | | | | | 1 500 | 2 400 | 2 606 | 4 787 | 16 550 |
| India | | | | | | | | | | 328 | 328 | 328 |
| Japan | | | | | | | | | | 8 640 | 16 120 | 17 260 |
| Korea | | | | | | | 29 | 59 | 115 | 151 | 449 | 1 075 |
| Netherlands | | | | | | 400 | 1 250 | 2 782 | 5 770 | 11 860 | 17 786 | 26 088 |
| Norway | | | | | | 2 800 | 3 105 | 3 688 | 4 511 | 5 185 | 5 289 | 7 105 |
| Sweden | | | | | | | | 500 | 1 000 | 1 070 | 1 824 | 2 215 |
| United Kingdom | | | | | | | 1 503 | 2 804 | 5 515 | 7 431 | 8 716 | 10 736 |
| United States | | | 333 | 339 | 373 | 482 | 3 903 | 11 695 | 14 990 | 20 115 | 28 150 | 35 089 |
| Others | | | | | | | 1 129 | 5 068 | 6 829 | 9 142 | 15 483 | 24 658 |
| Total | | | 333 | 339 | 373 | 3 682 | 10 919 | 29 618 | 44 002 | 91 494 | 159 072 | 212 394 |

Note: Slow chargers include AC Level 2 chargers (> 3.7 kW and ≤ 22 kW).

## Table 12 • Publicly accessible fast charger stock by country, 2005-16 (number of units)

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canada | | | | | | | | 2 | 7 | 55 | 147 | 315 |
| China | | | | | | | | | | 9 000 | 12 101 | 88 476 |
| France | | | | | | | | 9 | 102 | 127 | 543 | 1 231 |
| Germany | | | | | | | | 18 | 47 | 317 | 784 | 1 403 |
| India | | | | | | | | | | | | 25 |
| Japan | | | | | 95 | 312 | 801 | 1 381 | 1 794 | 2 877 | 5 990 | 5 990 |
| Korea | | | | | | | 33 | 118 | 177 | 237 | 489 | 750 |
| Netherlands | | | | | | | 15 | 63 | 106 | 269 | 528 | 701 |
| Norway | | | | | | 1 | 18 | 58 | 144 | 249 | 698 | 1 052 |
| Sweden | | | | | | | | 5 | 20 | 135 | 343 | 523 |
| United Kingdom | | | | | | | | 36 | 176 | 481 | 1 121 | 1 523 |
| United States | | | 42 | 42 | 47 | 60 | 489 | 1 464 | 1 877 | 2 518 | 3 524 | 5 384 |
| Others | | | | | | | 13 | 11 | 589 | 862 | 1 753 | 2 498 |
| Total | | | 42 | 42 | 142 | 373 | 1 369 | 3 165 | 5 039 | 17 127 | 28 021 | 109 871 |

Note: Fast chargers include AC 43 kW chargers, DC chargers, Tesla Superchargers and inductive chargers.

# EV support policies annex

| | Main EV support policies in 2016, changes from 2015 and 2017 | Source |
|---|---|---|
| **Canada** | Fuel economy standard including EV multipliers - Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations | CDOJ (2017) |
| | Waivers on fees (e.g. tolls, parking and ferries) in Ontario and Quebec<br>Access to HOV lanes in British Columbia, Ontario and Quebec | EVI country submissions |
| | Provincial-based purchase incentives: British Columbia, Ontario and Quebec | British Columbia (2016); OMOT (2010); Quebec (2012) |
| **China** | In 2016, implementation of the fourth stage of the fuel consumption standard framework | EVI country submissions |
| | Acquisition tax and excise tax exemption (depending on engine displacement and price) (CNY 35 000 to CNY 60 000) (USD 5 100 to USD 8 700) | EVI (2016a) |
| | Circulation and ownership tax exemption | EVI (2016a) |
| | Possibility of local subsidies within the limit of 50% of the amount granted via central subsidies | MoF (2017) |
| | From 2017, 20% reduction from 2016 subsidies, with the plan to adjust policies according to market response until 2020 | MoF (2017) |
| | In seven major urban centres, exemptions from licence plate access restrictions | EVI (2016a) |
| | Locally, access to bus lanes, exemption from access restrictions at peak times, free charging, free parking | EVI country submissions |
| **Denmark** | EU tailpipe emission standard (Euro 6 in 2016), EU fuel economy regulation | EVI (2016a) |
| | Registration tax exemption until 2015 and phase out between 2016 and 2022 (introduction of 20% of full tax rate for BEVs in 2016, full tax rate applicable by 2022)<br>Starting in 2017, battery capacity-based purchase tax rebate (USD 225/kWh with maximum 45 kWh) | IEA HEV TCP (forthcoming) |
| **France** | EU tailpipe emission standard (Euro 6 in 2016), EU fuel economy regulation | EVI (2016a) |
| | $CO_2$/km-based eco bonus-malus scheme (bonus of EUR 6 300 (USD 6 900) for BEVs and EUR 1 000 (USD 1 100) for PHEVs, up to EUR 10 000 (USD 11 000) for BEVs and EUR 3 500 (USD 3 900) for PHEVs when returning an old diesel car) | EVI (2016a); Autonews (2016); MEEM (2016b) |
| | Company car tax credits<br>Electricity and hydrogen tax exemption<br>From 2017, government fleet commitment of 50% of renewals being EVs, and 20% for local authorities<br>From 2017, government fleet commitment of 50% of renewals being EVs, and 20% for local authorities | EVI country submissions |
| **Germany** | EU tailpipe emission standard (Euro 6 in 2016), EU fuel economy regulation | EVI (2016a) |
| | Purchase rebates of EUR 4000 (USD 4 400) for BEVs and EUR 3 000 (USD 3 300) for PHEVs, at the limit of 400 000 cars until 2020 or EUR 600 million (USD 674 million)<br>Automakers should provide half of the incentive amount, the government covering the other half | EAFO (2017a) |
| | Ten-year circulation tax exemption, reduced to five years from 2021 | EVI (2016a); EAFO (2017a) |
| | Tax deduction for company cars | EAFO (2017a) |
| | Differentiated plates for EVs, allowing for differentiated measures | EAFO (2017a) |
| | Locally, free parking, dedicated parking and access to bus lanes | EAFO (2017a) |

| | Main EV support policies in 2016, changes from 2015 and 2017 | Source |
|---|---|---|
| **India** | Tailpipe emission standard (Bharat 3, equivalent Euro 6) | EVI (2016a) |
| | FAME Scheme (includes several components, such as demand incentives and pilot projects)<br>In some states, registration tax and VAT rebates or exemptions | EVI country submissions |
| **Japan** | Tailpipe emissions standard (PNLT 2009, equivalent to Euro 6)<br>Battery capacity and electric range-based purchase subsidy of JPY 850 000 (USD 7 700) maximum, e.g. 30 kWh-battery Nissan Leaf: JPY 330 000 (USD 3 000)<br>Locally, waivers on fees, access to restricted traffic | TransportPolicy.net (2016); EVI (2016a); EVI country submissions |
| **Netherlands** | EU tailpipe emission standard (Euro 6 in 2016), EU fuel economy regulation | EVI (2016a) |
| | In 2016, exemption from registration tax for BEVs, EUR 6/g$CO_2$/km for PHEVs. In 2017, increase of registration tax to EUR 20/g$CO_2$/km for PHEVs<br>Ownership tax exemption for BEVs, 50% discount for PHEVs (EUR 400 to EUR 1 200 for conventional cars)<br>$CO_2$/km-based taxation on the private use of a company car (in 2015, 4% income tax for BEVs, 7-14% for PHEVs; in 2016, increase to 15-21% for PHEVs; in 2017, increase to 22% for PHEVs (rate applicable to all powertrains except BEVs))<br>EVs are considered as tax deductible investments for companies | Energielabel (2016);<br>EAFO (2017a);<br>EVI country submissions |
| **Norway** | EU tailpipe emission standard (Euro 6 in 2016), EU fuel economy regulation | EVI (2016a) |
| | Purchase tax exemption (NOK 100 000) (USD 11 600) | |
| | VAT exemption for BEVs (25% of vehicle price before tax) | |
| | Further purchase rebates and purchase tax waivers introduced for PHEVs in 2016 (maintaining VAT)<br>VAT exemption for leased BEVs<br>Circulation tax exemption<br>Plan to maintain BEV taxation schemes until 2020 while possibility of revision of PHEV taxation schemes<br>Waiver on road tolls and ferry fees<br>From 2016, leadership on free parking measures transferred from the central level to the municipal level | EVI country submissions |
| **Korea** | Tailpipe emission standard CARB NMOG (equivalent to Euro 6) | TransportPolicy.net (2016) |
| | Central purchase subsidies of KRW 14 million (USD 12 329) for BEVs, KRW 5 million (USD 4 400) for PHEVs (rates applicable in 2016 and 2017)<br>Additional local purchase subsidies of KRW 3 million to KRW 12 million (USD 2 700 to USD 10 600 USD)<br>Tax reduction of around KRW 4 million (USD 3 540) for BEVs, KRW 2.7 million (USD 2 389) for PHEVs (rates applicable in 2016 and 2017) | EVI country submissions |
| | Upwards revision of 2020 target for EV deployment, from 200 000 in 2015, to 250 000 in 2016, as per the Plan for Fine Dust Management | MoE (2016) |

| | Main EV support policies in 2016, changes from 2015 and 2017 | Source |
|---|---|---|
| Sweden | EU tailpipe emission standard (Euro 6 in 2016), EU fuel economy regulation | EVI (2016a) |
| | Between 2011 and 2015, Super Green Car Premium purchase rebate of SEK 40 000 (USD 4 500) for BEVs and SEK 20 000 (USD 2 300) for PHEVs below 50 $gCO_2$/km; from 2016, reduction to SEK 20 000 for PHEVs | EAFO (2017a) |
| | Five-year exemption from annual circulation tax for EVs with a maximum fuel economy of 37 kWh/100km (equivalent to SEK 500 to SEK 3 000 per year (USD 57 to USD 340) | EAFO (2017a) |
| | For businesses, premium of 35% of the price difference between the purchased EV and the nearest comparable car, within the limit of SEK 40 000 (USD 4 500) for BEVs and SEK 20 000 (USD 2 300) for PHEVs | EVI country submissions |
| | For company cars, a reduction in fringe benefits value by 40% compared to a similar conventional car, within the limit of SEK 16 000 (USD 1 800) between 2012 and 2016 and SEK 10 000 (USD 1 100) from 2017 | EVI country submissions |
| | Company car tax reduction | EAFO (2017a) |
| United-Kingdom | EU tailpipe emission standard (Euro 6 in 2016), EU fuel economy regulation | EVI (2016a) |
| | $CO_2$/km-based and zero-emission range-based purchase subsidy scheme (GBP 4 500 (USD 5 800) for BEVs, GBP 2 500 (USD 3 300) for PHEVs) | Gov.uk (2017d) |
| | Tax incentives: fuel duty exemption, vehicle excise duty exemption for BEVs and discount for PHEVs, reduced taxation for company cars | Gov.uk (2016b); Gov.uk (2016c) |
| | Planned government spending of more than GBP 600 million (USD 770 million) (2015-20) to support ultra-low emission vehicle (ULEV) manufacturing and adoption (objective of 100% new ZEV sales by 2040) | Gov.uk (2015), Gov.uk (2016d) |
| | Go Ultra-Low City scheme (ULEV-friendly measures in a number of UK cities, including London): e.g. exemption from congestion charging, EVSE deployment, free parking and bus lane access | EAFO (2017a); GoUltraLow (2016) |
| | Go Ultra-Low communication campaign supported by government and OEMs | |
| United States | Corporate Average Fuel Economy (CAFE) standard with multipliers for EVs and alternative powertrains | GPO (2015) |
| | Tax credit of USD 2 500 to USD 7 500 to be phased out after 200 000 units per manufacturer are sold for use within the country | EVI country submissions |
| | ZEV production mandates in place in nine states | |
| | In some states, purchase rebates and registration tax exemptions | |

Notes: When no vehicle type is specified, the policy measure described refers to electric cars (both BEVs and PHEVs).
The ten US states following the California ZEV mandate are California, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont.

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# Acronyms, abbreviations and units of measure

## Acronyms and abbreviations

| | |
|---|---|
| 2DS | two-degree scenario |
| AC | alternating current |
| BEV | battery-electric vehicle |
| B2DS | beyond-two-degree scenario |
| CAFE | Corporate Average Fuel Economy |
| CCS | combined charging system |
| CEM | Clean Energy Ministerial |
| $CO_2$ | carbon dioxide |
| COP21 | 21st Conference of the Parties to the United Nations Framework Convention on Climate Change |
| DC | direct current |
| DSO | demand-side operator |
| EU | European Union |
| EV | electric vehicle |
| EVI | Electric Vehicles Initiative |
| EVSE | electric vehicle supply equipment |
| FCEV | fuel cell electric vehicle |
| GHG | greenhouse gas |
| GIZ | German Corporation for International Cooperation |
| HEV | hybrid and electric vehicles |
| HGV | heavy-goods vehicles |
| HOV | high-occupancy vehicle |
| ICCT | International Council on Clean Transportation |
| ICE | internal combustion engine |
| ICT | information and communications technology |
| IEA | International Energy Agency |
| IEC | International Electrotechnical Commission |
| IRENA | International Renewable Energy Agency |
| ISO | International Organization for Standardization |
| LSEV | low-speed electric vehicle |
| OEM | original equipment manufacturer |
| PHEV | plug-in hybrid electric vehicle |

| | |
|---|---|
| PLDV | passenger light-duty vehicle |
| PPP | public-private partnership |
| RD&D | research, development and deployment |
| RTS | Reference Technology Scenario |
| SAC | Standardization Administration of China |
| SAE | Society of Automotive Engineers |
| TCP | technology collaboration programme |
| TCO | total cost of ownership |
| UK | United Kingdom |
| US | United States |
| US DOE | US Department of Energy |
| ULEV | ultra-low emission vehicle |
| ULEZ | ultra-low emission zone |
| UNEP | United Nations Environment Programme |
| UNIDO | United Nations Industrial Development Organization |
| VAT | value-added tax |
| WTW | well-to-wheel |
| ZEV | zero-emission vehicle |

# Units of measurement

| | |
|---|---|
| $gCO_2$ | gramme of carbon dioxide per km |
| $gCO_2$/km | gramme of carbon dioxide per kilometre |
| $gCO_2$/kWh | gramme of carbon dioxide per kilowatt hour |
| Gt | gigatonne |
| GW | gigawatt |
| km/Lge | kilometre per litre of gasoline-equivalent |
| kW | kilowatt |
| kWh | kilowatt hour |

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Typeset in France by IEA, June 2017

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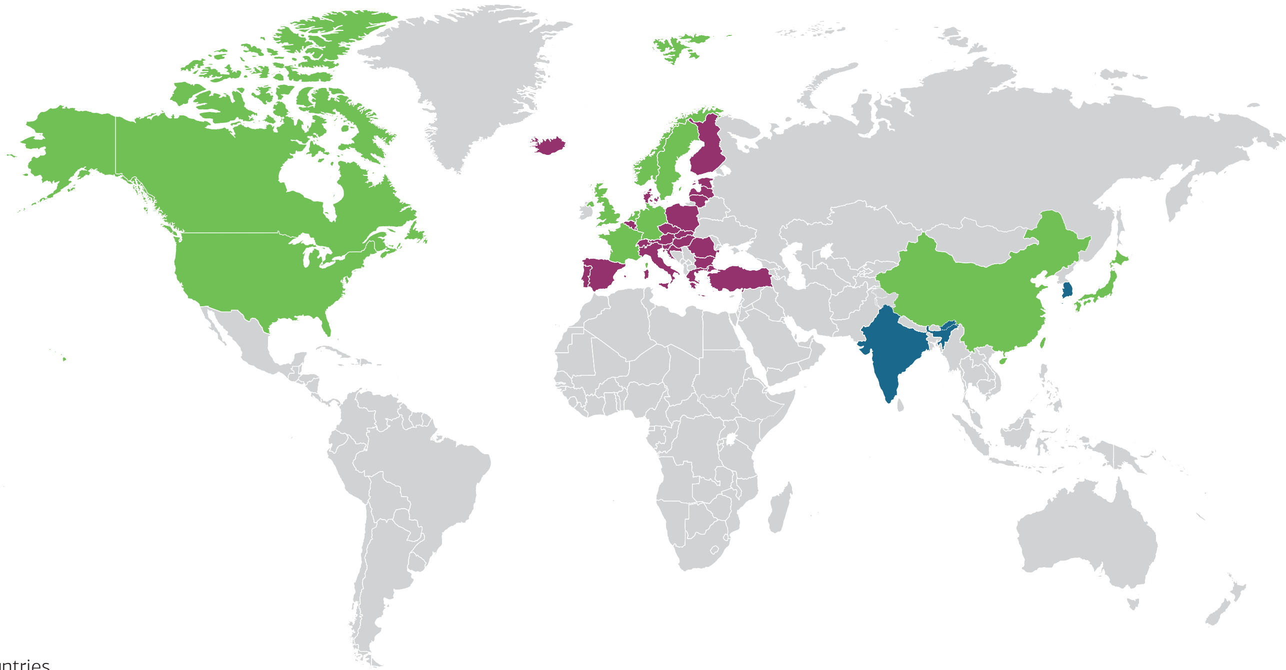
# Electric Vehicles Initiative

The EVI is a multigovernment policy forum established in 2009 under the Clean Energy Ministerial, dedicated to accelerating the deployment of EVs worldwide. It brings together representatives of its member governments and partners twice per year and acts as an effective platform for knowledge-sharing on policies and programmes that support EV deployment. In 2017, it launched the EV30@30 campaign, redefining its ambition by setting the collective aspirational goal for all EVI members of a 30% market share for electric vehicles in the total of all passenger cars, light commercial vehicles, buses and trucks, by 2030.

The EVI counts today ten member governments (Canada, China, France, Germany, Japan, the Netherlands, Norway, Sweden, the United Kingdom and the United States), representing most of the global EV stock and including the largest and most rapidly growing EV markets worldwide. China and the United States are currently co-leading the EVI*, and the IEA is the co-ordinator of the initiative.

* United States' leadership under review



- EVI countries
- European Alternative Fuels Observatory (EAFO) countries not in EVI
- Other countries that contributed to the EVI data collection

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Electric Vehicles Initiative