WHITE PAPER

FEBRUARY 2020

ANALYZING POLICIES TO GROW THE ELECTRIC VEHICLE MARKET IN EUROPEAN CITIES

Sandra Wappelhorst, Dale Hall, Mike Nicholas, Nic Lutsey
International Council on Clean Transportation

www.theicct.org

communications@theicct.org

twitter @theicct

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

BEIJING | BERLIN | SAN FRANCISCO | WASHINGTON

ACKNOWLEDGMENTS

This work was conducted with generous support from the European Climate Foundation, the Mercator Foundation, and the Aspen Global Change Institute. Peter Mock, Nic Lutsey, Georg Bieker, and Hongyang Cui provided critical reviews on an earlier version of this report. Any errors are the authors' own.

International Council on Clean Transportation
Neue Promenade 6, 10178 Berlin

communications@theicct.org | www.theicct.org | @TheICCT

EXECUTIVE SUMMARY

Europe, now second only to China in growing the global electric vehicle market, has richly varied electric mobility support policies across its markets. Specifically, European Union-level regulation supports electric vehicle deployment, but national and local actions vary. A broad mix of policies across government levels can overcome key barriers of electric vehicle affordability, convenience, and awareness. Investigation of the underlying policy and market dynamics is critical.

This report analyzes market trends and key national and local electric vehicle promotion policies across Europe. Electric vehicle uptake and policies for passenger cars are assessed for 15 metropolitan areas: Amsterdam, Berlin, Birmingham, Brussels, Copenhagen, Hamburg, Helsinki, London, Madrid, Oslo, Paris, Rotterdam-The Hague, Stockholm, Vienna, and Zurich. These areas represent high uptake markets with diverse support activities within the greatest national electric vehicle markets. The analysis focuses on key policies and the effects of incentives, charging infrastructure, and model availability on electric vehicle uptake.

Figure ES-1 illustrates electric vehicle share of new passenger car registrations in 200 metropolitan areas with more than 250,000 inhabitants in 2018, highlighting the 15 areas of our analysis.

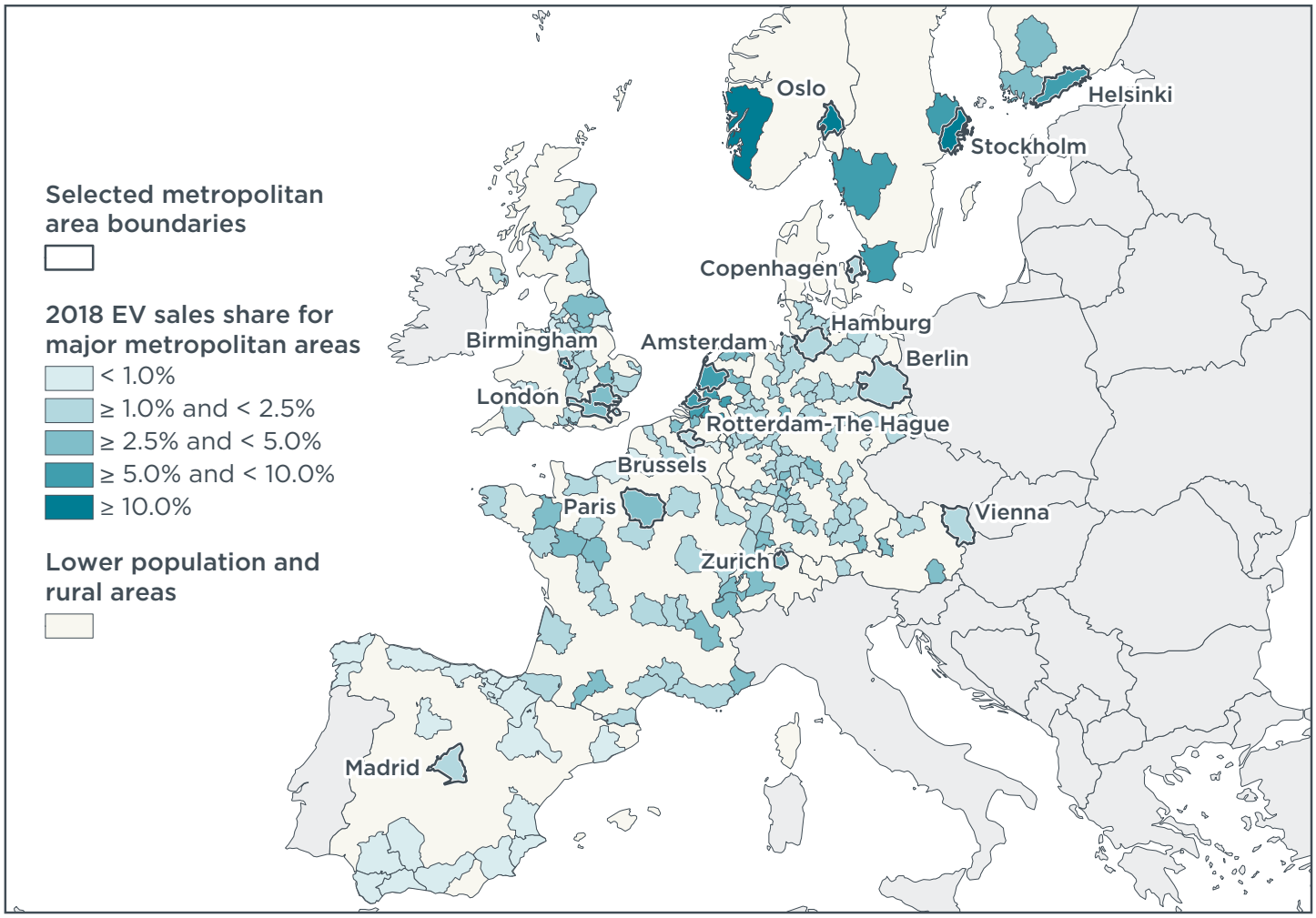

Figure ES-1. Electric vehicle share of new registrations in major European metropolitan areas.

The figure shows that, in 2018, electric vehicle uptake, including battery electric vehicles and plug-in hybrid electric vehicles, differed considerably across areas and

countries. Electric shares were particularly high in Norway (Oslo 61%, Bergen 64%), Sweden (Stockholm 13%, Gothenburg 6%), the Netherlands (Amsterdam 7%, Utrecht 6%), Finland (Helsinki 6%), and the United Kingdom (Birmingham 5%). In contrast, most areas in Spain had lower uptake, including Madrid with a 1.7% electric vehicle share.

Based on our assessment of the overall market and in-depth analysis of 15 selected metropolitan areas, the following main recommendations can be made for national and local governments looking to accelerate electric vehicle uptake.

Apply a comprehensive mix of electric vehicle promotion actions. Most high electric vehicle-uptake markets have adopted policies addressing the various prevailing consumer barriers of affordability, convenience, and awareness. London, Oslo, and Stockholm typify this broad approach, with at least 15 actions each (of 20 actions catalogued) across city and national levels. This research identifies the key action areas: financial incentives to bridge the cost gap between electric and conventional cars; programs to deploy charging infrastructure; and information campaigns to raise awareness and increase visibility regarding available electric vehicles and their benefits.

Introduce significant cost advantages for electric vehicles. Higher purchase costs for electric vehicles compared to combustion-powered vehicles remain a barrier for many consumers. National and local one-time purchase subsidies and annual national tax breaks on vehicle registration and operation are common where electric shares are high—for example in Amsterdam, Oslo, and The Hague. In contrast, markets which have largely not addressed cost barriers on car purchase or annual ownership tax (e.g., Brussels, Madrid) typically see slower electric uptake. Additional policies such as discounts or exemptions on parking fees or parking permits, charging an electric vehicle, road tolls, and congestion charges can be powerful instruments at the local level to supplement national policies to provide further cost advantages for electric vehicle drivers.

Support charging infrastructure to assure consumer convenience. Amsterdam, Oslo, Stockholm, and The Hague have built up dense networks of public charge points and experienced among the highest electric vehicle sales shares in the world. In addition, they have different local and national programs in place that support home and workplace charging. In markets such as Hamburg and Copenhagen with a dense network of public charging infrastructure but a slower electric vehicle uptake, additional local actions (e.g., building codes, zoning, regulations, tax exemptions) to support the charging infrastructure—home, workplace, curbside—are key, especially as the market broadens to those without dedicated home charging.

As governments increasingly set higher targets for electric vehicles, European- and national-level policies including CO_2 standards and bonus-malus programs will be crucial to accomplish these goals. At the same time, cities have a key role to play in implementing policies, building infrastructure, and taking advantage of local conditions to overcome barriers to adoption. Although the market is still developing, city leadership is demonstrating the path to transportation electrification in Europe.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Europe as a region is the second-largest market for electric vehicles globally, trailing only China. In 2018, Europe's electric passenger vehicle (EV) sales, including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), accounted for 20% of the global total, compared to 50% in China and 19% in United States. In absolute numbers, European electric vehicle sales increased by 34% from approximately 300,000 in 2017 to more than 400,000 in 2018.

Electric vehicle uptake varies greatly across Europe. Figure 1 shows cumulative electric vehicle sales from 2009 to 2018, as well as 2018 electric vehicle sales share, for the Member States of the European Union (EU) (excluding Lichtenstein) as well as Norway, Iceland, and Switzerland in the European Free Trade Area (EFTA). The information shown is based on data from EV-Volumes (2019) and the European Alternative Fuels Observatory (2019). In 2018, more than 50% of new cars sold in Norway were electric vehicles, bringing the cumulative total of electric vehicles sold in the country to almost 270,000. Iceland, although a much smaller market with 8,000 cumulative electric vehicles, ranked second with a 19% electric share in 2018. Following Norway, Germany (211,000), France (205,000) and the United Kingdom (203,000) experienced the highest absolute electric sales over the last 10 years, followed by the Netherlands (149,000), Sweden (81,000), and Belgium (47,000). In contrast, 14 out of 30 European countries had fewer than 5,000 cumulative electric vehicle sales between 2009 and 2018, mostly representing Eastern European countries.

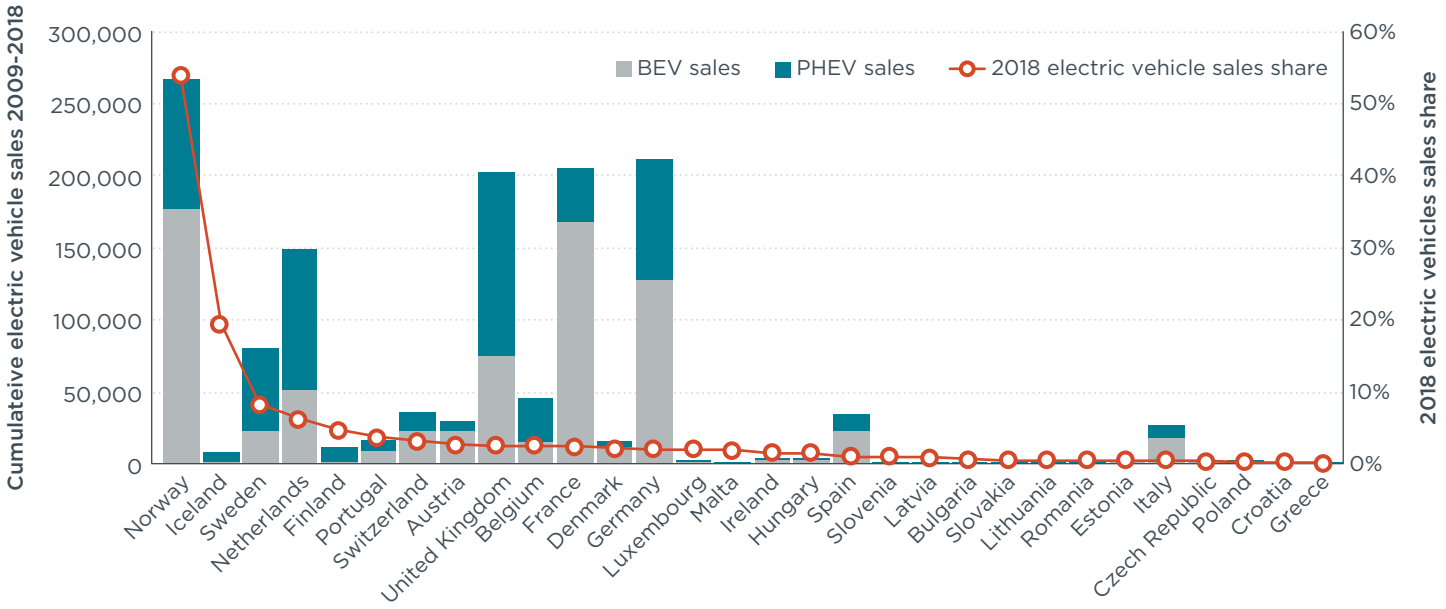

Figure 1. Cumulative electric vehicle sales from 2009 to 2018, and 2018 electric vehicle sales share.

These electric vehicle uptake developments are affected by a multitude of polices that break down the prevailing barriers to electric vehicle consumer uptake. European and national policies like regulations and incentives assure manufacturer investments and vehicle deployment, and reduce the electric vehicle upfront cost differences. As high concentrations of motorized traffic greatly exacerbate urban air pollution and climate change, cities have begun to use their authority to develop policies intended to steer and accelerate the transition to electric mobility. Limited availability of local-level data on electric vehicle uptake and associated policies, charging infrastructure, and local promotion activities often complicates the ability to assess the associated dynamics.

This analysis fills an important gap in the research literature in terms of quantifying electric vehicle uptake in Europe in relation to promotion actions, focusing on a

selection of major metropolitan areas. The selection is based on high population size, high electric vehicle share and sales in 2018, and diverse electric vehicle support activities within the top national European markets (as shown in Figure 1). The focus is on the following 15 metropolitan areas: Amsterdam, Berlin, Birmingham, Brussels, Copenhagen, Hamburg, Helsinki, London, Madrid, Oslo, Paris, Rotterdam-The Hague, Stockholm, Vienna, and Zurich. The 12 nations within which these 15 metropolitan areas are located account for 94% of cumulative electric vehicle sales in Europe (including the EU and EFTA) through 2018.

The focus of this paper is primarily on the metropolitan area-level variation, but national policies underlie the electric vehicle uptake in these locales. All national governments assessed have established some form of targets or goals for electric vehicle adoption. Norway's goal is to sell only zero-emission cars by 2025 (Ministry of Transport, 2017). Denmark and Sweden want to phase out the sale of combustion engine cars beyond 2030, the Netherlands wants all new passenger cars sold to be emission-free starting the same year (Regeringen, 2018; Rijksoverheid, n.d.; The Government of Denmark, 2018). The United Kingdom set their respective target for 2035, France and Spain for 2040 (Electrive.com, 2020; République Française, 2019; Congreso de los Disputados, 2019). To accomplish these goals, electric vehicle uptake targets specified by national governments vary among the countries. Germany, for example, initially aimed for 1 million electric vehicles on the road by 2020. The new target of the German government is 7 to 10 million electric vehicles registered by 2030 (Die Bundesregierung, 2009; Die Bundesregierung, 2019). France has set a goal of 1 million electric vehicles on the road by 2022 (Enedis, 2018), and Denmark aims for 1 million by 2030 (Regeringen, 2018).

The scope of the analysis is limited to light-duty passenger electric vehicles, which account for approximately 90% of all new vehicle registrations in Europe and well over 90% of Europe's electric vehicles (Mock, 2018). Although important strides are also being made in electric vans, commercial freight trucks, and buses, market developments for these segments are at earlier stages and they are excluded here. The definition of metropolitan areas is based on the European Union's Metropolitan Region definition (Eurostat, n.d.) to more systematically compare diverse urban areas while accounting for regional travel and economic patterns.[1]

The report analyzes electric vehicle market trends and quantitatively compares the trends against the associated policies to support the continued improvement of government electric vehicle action plans. The following section summarizes and catalogues national and local policies addressing prevailing obstacles related to electric vehicle affordability, convenience, and awareness across the metropolitan areas. The next section analyzes the link between incentives, charging availability, and promotion activities and electric vehicle uptake. The work concludes with the resulting findings on how national and local governments can greater encourage electric vehicle uptake.

1 The metropolitan regions are defined using NUTS3 statistical areas to approximate the shape of Functional Urban Areas, which represent urban agglomerations based on commuting patterns. More information can be found at Eurostat (n.d.).

ELECTRIC VEHICLE POLICIES IN EUROPE

Leading electric vehicle markets employ a variety of measures at national and local levels to address key barriers to consumer adoption such as financial benefits to bridge the cost gap between electric vehicles and conventional cars, charging infrastructure to increase convenience, and information activities to raise awareness. The following section provides an overview of selected national and local measures being used to foster electric vehicle uptake across the 15 European metropolitan areas selected for analysis.

Many electric vehicle promotion activities are used at national and local levels, and fiscal support measures and charging infrastructure deployment are among the more prominent ones. To bridge the cost gap between electric vehicles and conventional cars, national or local governments often provide consumer incentives in the form of one-time subsidies, tax breaks on vehicle purchase and operation, or preferred or free access to certain road infrastructure. Parking and charging benefits addressing the cost factor are mostly deployed at the local level. The rollout of charging infrastructure—publicly accessible as well as home and workplace charging options—aims at increasing the convenience for electric vehicle owners recharging their vehicles. Local and national promotion actions include financial support programs targeted at specific consumer segments, ranging from homeowners and companies to public bodies.

Beyond fiscal measures and charging infrastructure, many additional information and local action planning activities are also being more broadly deployed. To increase the awareness about electric vehicles, campaigns frequently including tailor-made information are common measures at local or national levels. In addition, the adoption of electrified municipal fleets help to increase the technology's visibility. Strategic plans and legal regulations regarding electric vehicle sales volume or share—nationally and locally—serve as the underlying framework in driving electrification (Slowik & Lutsey, 2018).

Figure 2 gives an overview of the 20 policy measures selected for this analysis. Some of these measures apply to both national and local levels. Policies that are not applied throughout the whole metropolitan area but implemented in certain municipalities or boroughs are also included. The analysis covers policies for the year 2018 to assess the potential link to electric vehicle sales for the same year. Selected policies introduced in 2019 also are highlighted to indicate policy developments since the 2018 electric vehicle data collected.

The effect of Europe-wide measures, such as the regulation of the CO_2 emissions of newly registered vehicles, and of the policy-stimulated development in non-European electric vehicle markets on the availability and cost of electric vehicle models are briefly discussed in the conclusion.

Electric vehicle purchase and operation	Electric vehicle charging infrastructure	Electric vehicle strategies, procurement, and public awareness
National • BEV purchase benefit[1] • PHEV purchase benefit[1] • BEV registration tax benefit[2] • PHEV registration tax benefit[2] • BEV ownership tax benefit[2] • PHEV ownership tax benefit[2] • EV company car benefit for employees	**National** • Public charger promotion • Private and workplace charger promotion	
Local • EV parking benefit • EV charging benefit • EV infrastructure use and access benefit	**Local** • Public charger promotion • Private and workplace charger promotion • EV curbside charging program • EV-ready building codes • EV charging interoperability requirements	**Local** • EV goals • Public EV procurement • EV information and awareness raising

[1] In some countries, additional local purchase benefits exist. As they usually only aim at certain target groups, we mention them in our description, but leave them out for our quantitative analysis.
[2] In some countries (Belgium, Switzerland), regulations have been transferred to local levels.

Figure 2. Selected promotion actions assessed as part of the analysis.

The following subsections describe the selected promotion actions and how they are implemented in the different metropolitan areas. The results are illustrated in a summary overview at the end this section (Figure 3).

ELECTRIC VEHICLE PURCHASE AND OPERATION

Promotion actions addressing vehicle purchase and operation are largely focused on breaking down the cost gap between electric and combustion engine vehicles. The analysis considers one-time subsidies and tax benefits on vehicle purchase as well as tax breaks for operating a vehicle in private ownership as well as company-owned cars, usually applied at national the level. Further measures addressing the affordability of electric vehicles included in the analysis focus on parking and charging benefits as well as preferential charges for using road infrastructure or access to restricted urban areas as applied at the local level.

BEV and PHEV purchase benefit. National incentives on car purchases have been major components of electric vehicle policies in Europe. In 2018, consumers in nine cities within the selected countries benefited from national purchase grants. These cities included Berlin, Birmingham, Copenhagen, Hamburg, Helsinki, London, Paris, Stockholm, and Vienna. National grant amounts for BEV and PHEV purchasers ranged between about €1,000 (Sweden) and €6,000 (France) with most countries applying higher rates for BEVs. Grantees were typically individuals and businesses who could apply for grants for different vehicle types, including passenger cars and commercial vehicles (e.g. Transport Styrelsen, n.d.; Ministry of Ecological and Solidarity Transition, 2018).

For the sake of completeness, local incentives are mentioned here, as well. However, they are not taken into account in the summary overview, as in contrast to national bonus payments, local one-time grants usually aim at more specific target groups. These groups can include businesses, taxi companies, driving schools, or carsharing organizations. In 2018, local grants were applied in cities and metropolitan areas such as Amsterdam, Berlin, the Greater Paris area, Madrid, Rotterdam-The Hague, and

Vienna (Municipality of Amsterdam, n.d.b; Investitionsbank Berlin, 2018; Paris, 2019a; Madrid City Council, 2017; Municipality of Rotterdam, n.d.; Wiener Stadtwerke, 2019).

BEV and PHEV registration tax benefit. Tax benefits when registering a vehicle for the first time have been an additional important action to grow the electric vehicle market. Reduced rates or exemptions on registering an electric vehicle were applicable in 11 cities in 2018 (Amsterdam, Birmingham, Brussels, Copenhagen, Helsinki, London, Madrid, Oslo, Paris, Rotterdam-The Hague, and Stockholm). In Brussels metropolitan area, only buyers of a BEV could benefit from exemptions on registration tax while all other markets addressed BEVs and PHEVs equally. Austria, Germany, and Switzerland do not apply registration tax. France and Sweden have a bonus-malus tax scheme in place, integrating a bonus payment for electric vehicles on registration (see previous paragraph) (Transport Styrelsen, n.d.; Ministry of Ecological and Solidarity Transition, 2018). Norway is the only country where buyers of a BEV are exempted from paying value added tax (VAT), which is 25% of the vehicle's net price (Norsk elbilforening, n.d.).

BEV and PHEV ownership tax benefit. Tax advantages for owning a vehicle have been one of the key measures at national and partly local levels in electric vehicle adoption. In 2018, owners of an electric vehicle in 14 cities did benefit from tax exemptions or reductions compared to drivers of conventional cars. In Brussels, Oslo, and Vienna, only owners of a BEV could benefit from a tax break. In France, ownership tax applies for vehicles emitting more than 190 g CO_2/km, hence most vehicle owners were exempt from ownership tax. Norway replaced the tax in 2018 with a road traffic insurance tax, collected by the insurance companies on behalf of the authorities (ACEA, 2018; Norwegian Tax Administration, n.d.).

Electric vehicle company car benefit for employees. Because in many countries new passenger car registrations by companies outpace those purchased for private use, tax breaks for an electric company car have been a crucial policy instrument in Europe. For example in Sweden, 66% of all new vehicles registered in 2018 were by companies; in Germany, the share was 64%, and in the United Kingdom 55% (KBA, 2019; SCB, 2019; SMMT, 2019). Employees using a company car for private purposes have to tax the benefit in kind on income tax. In all cities with the exception of Paris and Zurich, employees privately using an electric company car benefited from national tax advantages in 2018 (Table 1, tax rules are simplified). Benefits included reduced coefficients applied to the vehicle's purchase price (Austria, Belgium, Netherlands, Sweden, United Kingdom), a fixed percentage tax reduction of the vehicle's purchase price (Norway, Spain), or a reduction based on the battery capacity of a vehicle (Germany). Some countries applied additional rates for trips between work and home to the benefit in kind. In Finland, this rate was lower for BEVs compared to conventional cars. In Denmark, an environmental fee was added to the taxable amount, which was lower for BEVs and PHEVs than for conventional cars. In 2019, Germany halved the yearly taxable percentage rate for electric vehicles from 12% to 6% of the vehicle's purchase price. From 2020, this preferable rate will be halved again to 3%, applicable for BEVs up to €40,000 (Wappelhorst, Mock, & Yang, 2018; Deutscher Bundestag, 2018; NWB Verlag, 2019). The United Kingdom will reduce the taxable base for electric vehicles in the upcoming years, from 13% of the vehicle's purchase price—the lowest taxable rate in 2018—to a full exemption for BEVs and 2% of the vehicle's purchase price for PHEVs in 2020 (FleetNews, 2019).

Table 1. Selected national tax benefits for employees privately using electric company cars for the year 2018.

Market	Company car tax benefit for employees privately using an electric company car in 2018
Amsterdam, Rotterdam-The Hague (Netherlands)	Benefit for **BEVs:** 4% yearly rate of the vehicle's catalogue value if the car emits 0 g CO_2/km. 22% for cars emitting more than 0 g CO_2/km.
Berlin, Hamburg (Germany)	Benefit for **BEVs and PHEVs:** Tax adjustment based on the battery capacity of the vehicle (compensation loss payment) which is €250 per kilowatt-hour battery capacity, with a maximum of €7,500.
Brussels (Belgium)	Benefits for **BEVs:** 4% yearly rate of the vehicle's gross price if the company car emits 0 g CO_2/km. 5.5% for cars emitting more than 0 g CO_2/km.
Copenhagen (Denmark)	Benefits for **BEVs and PHEVs:** An environmental fee added to the taxable amount which is lower for BEVs and PHEVs compared to conventional cars.
Helsinki (Finland)	Benefits for **BEVs**: Monthly unlimited benefit of 1.4% of the car's purchase price subtracted based on vehicle operating costs – fixed monthly base rate for trips between home and work of €120 or €0.08/km is subtracted; in case of other vehicle types, a monthly rate of €255 or €0.17/km is added.
London, Birmingham (United Kingdom)	Benefit for **BEVs and PHEVs:** Vehicles emitting up to 50 g CO_2/km pay a minimum percentage rate of 13% of the vehicle's list price. Coefficients for vehicles with higher emissions range between 16% and 37%.
Madrid (Spain)	Benefit for **BEVs and PHEVs:** 30% reduction on the vehicle's gross price.
Oslo (Norway)	Benefit for **BEVs:** The calculation base is 60% of the vehicle's list price rather than 100% which is applied to vehicles with emissions higher than 0 g CO_2/km.
Stockholm (Sweden)	Benefit for **BEVs and PHEVs:** The vehicle's purchase price is adjusted to a comparable conventional car and then, the benefit value is adjusted down by 40%, at most by SEK10,000 (about €1,000).
Vienna (Austria)	Benefits for **BEVs:** No benefit in kind payable as part of income tax if the car emits 0 g CO_2/km. Vehicles emitting between 1 and 124 g CO_2/km pay yearly 18% of the vehicle's gross price. Cars with CO_2 emissions over 124 g/km pay 24%.

Electric vehicle parking benefit. Parking benefits such as exemptions or reductions on parking fees or preferential parking access and permits at the local level have been a common measure to spur electric vehicle uptake in the transition phase. Ten cities offered some form of parking benefits for users of an electric vehicle in 2018—Amsterdam, Berlin, Brussels, Hamburg, Helsinki, London, Madrid, Oslo, Paris, and Vienna. In Madrid's city center, drivers of a zero-emission vehicle could park without time limitation (Madrid City Council, 2018a). Reduced parking fees for electric vehicle drivers were applied in the city centers such as Helsinki (City of Helsinki, 2018a). Time-limited, free parking applied in Berlin, Hamburg, Paris, and Vienna (ADAC, 2019; Paris, 2019b; Wien Energie, n.d.a). In Amsterdam, residents and companies owning an electric vehicle were given priority on the waiting list for parking permits (Municipality of Amsterdam, n.d.d). In Greater London, some of the boroughs offered discounted or free parking or parking permits (City of Westminster, n.d.; The Royal Borough of Kensington and Chelsea, 2019; Hammersmith and Fulham, 2019). In Brussels, companies that equip their parking space for visitors or staff with a charge point for an electric vehicle were offered tax exemptions, saving €75 of tax per car per year (City of Brussels, n.d.). Oslo granted free parking in public parking lots only for drivers of a BEV (Municipality of Oslo, n.d.a).

Electric vehicle charging benefit. Despite addressing potential cost barriers in the initial phase of electric vehicle adoption, city-specific programs that offer free or reduced fees for charging electric vehicles at public charge points have been a less widespread measure. Only three of the 15 cities offered charging benefits for electric vehicles in 2018 (Oslo, Paris, and Vienna). In Oslo, up to the beginning of 2019, drivers of an electric car did not have to pay for charging their vehicle (Electrive.com, 2019). Paris offered a flat rate for charging of €120 per year for individual and professional users and €600 for professionals operating the vehicle commercially, such as

carsharing or vehicle-for-hire operators and taxi companies (Paris, 2019c). Vienna conducted a half-year free charging trial that was not extended (Vienna Online, 2018).

Electric vehicle infrastructure use and access benefit. Few markets so far have implemented free, reduced-price, or preferential use of road infrastructure, which is to say exemptions on road tolls and congestion charges as well as preferential access to specific roads and zones (e.g., bus lanes, high occupancy vehicle lanes, low-emission zones) as an incentive in the early transition phase to electric vehicles.

Low-emission zones (LEZs) or ultra-low emission zones (ULEZs) restricting the access for most polluting vehicles to city centers—permanently or in the event of heavy air pollution—were applied in 2018 to passenger cars in cities such as Amsterdam (taxis only), Berlin, Brussels, London, Madrid, Oslo, Paris, Rotterdam, and Vienna. However, in 2018 Madrid was the only city that allowed only zero-emission vehicles to circulate and park without time limitation in the Residential Priority Areas (applicable until the end of 2018) and the extended inner-city LEZ introduced in November 2018 (Madrid City Council, 2018b; Parclick, n.d.). Future plans to grant access to certain areas or the whole city only to electric vehicles exist in Amsterdam, London, Oslo, and Paris. The mayor of London seeks to implement zero-emission zones (ZEZs) in the city's town centers from 2020 and aims to expand these to a ZEZ covering central London from 2025 (Mayor of London, 2018). Oslo aims at a fossil-free city center by 2024 (City of Oslo, 2017). In Amsterdam and Paris, from 2030 onward, it is planned to only allow zero-emission vehicles including passenger cars to the city or city center (Municipality of Amsterdam, n.d.a; Mairie de Paris, 2018). Brussels plans to ban all combustion engine vehicles by 2035 (Région de Bruxelles-Capitale, 2019). Other cities have not yet formulated similar goals for their LEZs.

Oslo and London also have a congestion charging zone in place in addition to their LEZ or ULEZ. In Oslo, charges for using local toll roads vary with fuel type and time of day. In 2018, zero-emission vehicles were exempt from fees for passing local toll roads whereas PHEV and combustion vehicle drivers had to pay a maximum of €6 during and €5 outside rush hours (Amundsen & Sundvor, 2018). In London, daily congestion charges for entering the inner-city zone of €13 during charging hours were waived for vehicles emitting up to 75 g CO_2/km. Although Stockholm already has phased out exemptions for electric vehicles on its congestion charge in the past (Swedish Transport Agency, n.d.), Oslo and London will follow a similar approach in future years. In London, from October 2021, exemptions from congestion charges will apply only to zero-emission vehicles. Starting in 2026, drivers of BEVs will also be required to pay the congestion charge (Mayor of London & Transport for London, 2018).

In terms of preferential access to certain road infrastructure, this has partially been introduced in Madrid, Oslo, and Rotterdam. In Madrid, electric vehicles can circulate along the high occupancy vehicle (HOV) lanes with a single occupant, although these lanes usually are reserved for vehicles with at least two persons (RACC, 2019). In Oslo, access to designated bus lanes was granted to BEV drivers in 2018 if carpooling with at least one other passenger. In Rotterdam, electric taxis were allowed to use a certain number of bus lanes (Terberg Leasing, 2018).

ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

Providing sufficient options for recharging an electric vehicle at convenient locations is a key to drive electrification. Extending the public charger network is mainly aimed at increasing their visibility and the consumer's convenience for recharging an electric vehicle, as well as reducing potential mental barriers. Workplace and home charging play an important role in charging an electric vehicle in the direct living environment. In addition, curbside installations can provide charging in dense inner-city or residential areas where charging options are limited. Building codes can establish electric vehicle infrastructure requirements for new or redeveloped construction projects, preparing

for the growing numbers of electric vehicles and improving access for consumers opting for an electric vehicle. Next to the physical charging infrastructure, mandating open access and interoperability in charging infrastructure plays in important role in increasing consumer acceptance and stimulating further uptake of electric vehicles.

Public charger promotion (national). Promotion actions for the deployment of the public charging network have been a widely adopted measure at the national level to provide critical charging opportunities for those who do not have home or workplace charging. In 2018, almost all national governments provided funding for the deployment of the public charging infrastructure (see Table 2). Beneficiaries of the various national programs covered a range of consumer groups including municipalities, associations, public institutions, small and medium-sized businesses, or residential collectives. Funding amounts ranged from €4.8 million by the Finnish government to €300 million allocated by the German government with varying funding periods (Korkia, 2019; Federal Ministry of Transport and Digital Infrastructure, 2019).

Table 2. Selected national public charger promotion actions in 2018

Market	Program	Funding source
Austria	National support program for the installation of public charging stations (pedestal or wall box). The support ranges between €200 and €10,000 depending on the kilowatt rating of the charging station. Beneficiaries include companies, associations, religious denominations, and public authorities.	Austrian government (Kommunalkredit Public Consulting GmbH, 2019)
Finland	National support program for the development of electric vehicle public charging infrastructure with a total €4.8 million in 2017–2019. The subsidy rate for fast charge points is 35%; for normal charge points it is 30%. The investment aid is aimed at companies.	Finnish government (Korkia, 2019)
France	Since 2016, the French government has been running the Advenir program, including subsidies for public charging points. Companies and public entities can receive up to 40% of the costs for the supply and installation of a charging point to a maximum of €1,860.	French government (République Française, 2018; Avere-France, 2019)
Germany	The German government is supporting the expansion of public fast and normal charging points with €300 million from 2017 to 2020. Beneficiaries are private investors as well as cities and municipalities.	German government, Federal Ministry of Transport and Digital Infrastructure (Federal Ministry of Transport and Digital Infrastructure, 2019)
Netherlands	The Dutch government granted help for publicly accessible charging infrastructure for electric cars with the framework of the Green Deal "Publicly Accessible Electric Charging Infrastructure." The program ran from mid-2015 to July 2018 with a total budget of €7.2 million. Beneficiaries were local and regional authorities.	Dutch government, Ministry of Economic Affairs and Infrastructure and Ministry of Water Management (Netherlands Enterprise Agency, n.d.)
Norway	Programs focus on the deployment of fast charge points at least every 50 km on the highway network. The company Enova has pledged support for NOK50.5 million (€5.3 million) for the establishment of 230 fast charge points.	Enova, owned by the Ministry of Petroleum and Energy (Ministries' security and service organization, 2017)
Spain	Aid program in 2018 for the implementation of the recharging stations including public charging stations within the framework of the MOVALT Infrastructure Plan. A total of €20 million were made available (including funding for private charge points). Grant amounts were 60% of the eligible investment for public entities and 40% of eligible for other companies.	Spanish government (Institute for Diversification and Energy Saving, 2018)
Sweden	Funding program for the installation of public charging infrastructure with a maximum of 50% of the investment cost.	Swedish government, Ministry of the Environment and Energy (Sweden's Parliament, 2015)
Switzerland	The Swiss government plays a supporting role in the coordination and planning of the public charging infrastructure. The responsible body is Energie Schweiz (Swiss Energy).	Swiss government (Federal Office of Energy, n.d.)
United Kingdom	On-street Residential Chargepoint Scheme, launched 2016, provides grant funding for local authorities to install on-street charging points. The allocated budget is £6 million (€7 million) from 2017 to 2020.	Department for Transport (Office for Low Emission Vehicles, 2019)

Public charger promotion (local). National funding for public charging infrastructure has been complemented by many local government actions. Beyond the national programs that partly provided funding for municipalities to extend the public charging network, nine cities have implemented additional measures. Amsterdam and Rotterdam-The Hague provided owners of an electric vehicle public charging infrastructure close to their place of residence or regular employment to respond more flexibly on demand (Municipality of Amsterdam, n.d.; Den Haag, n.d.). As mentioned before, Brussels offered tax exemptions for companies that equip their parking space with a charge point (City of Brussels, n.d.). Stockholm established charging streets with several charge points next to each other to increase consumer access and to simplify planning and implementation processes. For this purpose, the city gave land free of charge to electricity companies who then paid for the installation of the charging points (City of Stockholm, 2019). Helsinki followed a similar approach, leasing street spaces while an energy company delivered and operated the public charging infrastructure (City of Helsinki, 2017). In addition to collaborations with energy providers, Vienna involved local citizens to partially help finance the local public charging infrastructure. Citizens could purchase vouchers worth €250, refunded over a period of 5 years with yearly €55 or €65 for customers of the local energy provider Wien Energie (Wien Energie, 2017; Wien Energie, n.d.b). Other cities with local promotion actions included London, Oslo, and Paris.

Private and workplace charger promotion (national). As most vehicle recharging is done at home or at workplaces, many national governments have provided incentive or subsidy schemes for consumers at their residence or place of work. Nine cities benefited from national private and workplace charger promotion actions in 2018: Amsterdam, Birmingham, Helsinki, London, Madrid, Paris, Rotterdam-The Hague, Stockholm, and Vienna. National promotion actions included subsidies for the installation of charging infrastructure in Austria, Finland, the Netherlands, Spain, Sweden, the United Kingdom, or tax deductions in France aimed at private households, homeowners, tenants, housing associations, companies, or municipalities (Klima- und Energiefonds, 2018; Virta, 2018; Ministry of Economic Affairs, 2017; Institute for Diversification and Energy Saving, 2018; Swedish Ministry of Environment and Energy, 2017; Office for Low Emission Vehicles, 2018a, 2018b; Avere-France, 2017). Funds for the installation of home charging stations ranged from €200 (Austria) to €970 (Sweden). The United Kingdom set up a special scheme for home and workplace charging, offering a subsidy worth €570 in 2018.

Private and workplace charger promotion (local). Beyond national private and workplace charger promotions actions that also provide funding for different consumer groups at the local level, only a few markets have complemented those actions with city-specific schemes. Only Brussels, Oslo, and Paris had additional local policies in place. In Brussels, as stated previously, companies benefited from tax exemptions if they equip their parking spaces with a charge point (City of Brussels, n.d.). In Oslo, housing cooperatives for example could receive a maximum of over €100,000 for the installation of charging stations (Municipality of Oslo, n.d.b) and in Paris, housing collectives and taxi companies could receive a 50% aid for the installation of the charging infrastructure in 2018 (Paris, 2019a). Beneficiaries included housing collectives and co-owners, taxi companies, professional drivers of electric cars, or businesses. Similar to local public charger funding, in some cities funding was matched or exclusively provided by energy providers, for example as in the city of Vienna (Wien Energie, n.d.b).

Electric curbside and lamppost charging program. Programs that provide curbside charging points in dense inner-city areas or residential areas where charging options are limited have been a common policy action at the local level. With the exemption of Brussels where the first public charging point on public roads was installed as late as

end 2018 (City of Brussels, 2018), all other cities provided curbside programs, however with only a few that also started to implement lamppost charging. The United Kingdom launched a nationwide on-street residential charge point scheme in 2016 for electric drivers who could not have a home charge point installed, providing up to €8,500 towards a charge point (PitPoint, 2019). In metropolitan areas such as Amsterdam or Rotterdam-The Hague companies and individuals could request a charging station if they had no possibility to charge at home or at their workplace (City of Amsterdam, n.d.; Den Haag, n.d.). Similar to these cities, Oslo collaborated with private developers to install charging infrastructure and curbside charging (Berg, 2018). Stockholm also provided curbside space in 2018 and helped providers with the permissions (City of Stockholm, 2019). All other cities had programs for the installation of on-street charging facilities as part of the deployment of their public charging infrastructure network in place, also prior to the year 2018.

Large-scale programs for the deployment of lamppost charging were started in London in late-2018 (Fleet World, 2019; Office for Low Emission Vehicles, 2019). Berlin also announced the rebuilding of 1,000 streetlamps to charging points in certain areas of the city starting in 2020 (NGIN Mobility, 2019).

Electric vehicle-ready building codes. Obligations for setting up charging infrastructure or cabling in new buildings supplementing the access to charging points are not yet widely adopted across European markets. In 2018, only three cities had electric vehicle-ready building codes or standards in place, based on national or local regulations. At national the level, France adopted a national decree in 2016 that requires parking spaces in new building developments to be subsequently retroffited for recharging points, 50% or 75% of the parking spaces depending on the absolute number of parking spaces (République Française, 2016). Spain passed a national decree in 2014 that sets minimum provisions for the structure of recharging electric vehicles in new buildings or parking lots and on public roads, which is to say the preinstallation of electric wiring (Ministry of Industry, Energy and Tourism, 2014). At the city level, London's Parking Standards require 20% of parking spaces in residential developments for electric vehicles, as well as make-ready infrastructure for an additional 20% of parking spaces (Mayor of London, 2016). Vienna adapted its Garages Act at the end of 2018 adding requirements for the subsequent creation of charging spaces for electrically powered vehicles when constructing garages (Wiener Landtag, 2018). On a smaller scale, some cities, including Hamburg, have used administrative local instruments (e.g., urban development agreements and property purchase agreements) to require investors to install parking spaces and charging infrastructure in selected new building developments (HafenCity Universität Hamburg, 2018).

Electric charging interoperability requirements. The interoperability of public charging infrastructure in terms of using the charging networks of different charging infrastructure operators using the same payment methods to increase the consumer's convenience and accelerate electric vehicle adoption, has been partially implemented at national and local levels. The Netherlands has been a frontrunner in payment system interoperability. Charging an electric vehicle can be done with one single card at all public charging points in the Netherlands, including the metropolitan areas of Amsterdam and Rotterdam-The Hague. This has been achieved through the collaboration of many parties including energy and mobility providers as well as interest groups (Ministry of Economic Affairs, 2017). In Belgium, the Open Charge Point (OCP) brings together the main operators of the public charging infrastructure since 2015. Requirements include interoperability in terms of activation and payment methods (Open Charge Point Belgium, n.d.). At the local level, the city of Berlin provides a uniform charging card that grants access to all charging points in public areas independent of the charging operator, which also was in place in 2018 (Senate Department for Urban Development and Housing, 2015). Cross-supplier charging

was also possible in Vienna in 2018 (City of Vienna, 2019). In Hamburg, where every customer obtains their electricity from a self-selected supplier, the electricity suppliers established a framework contract with the distribution network operator to settle the transactions with the customer to guarantee user-friendly access to the public charging infrastructure network (Erle, 2016). In Stockholm, charging installed as part of the city plan must be interoperable and requires consistent payment methods (City of Stockholm, 2019).

ELECTRIC VEHICLE STRATEGIES, PROCUREMENT, AND PUBLIC AWARENESS

Additional policies are leveraged in selected cities to promote electric vehicles. Strategies and programs formulating goals and measures to stimulate electric vehicle adoption help to set the strategic framework for future actions. In addition, procurement programs can help increase demand for electric vehicles. The lack of information or misperceptions about electric vehicles often hinder consumers from opting for an electric car. Information and awareness-raising campaigns can therefore be crucial in the transition to electric vehicles.

Electric vehicle goals. Strategies and programs that set electric vehicle uptake targets or goals are typical measures undertaken at the local level. Next to the national goals described above, all cities with the exception of Zurich had some form of goals and targets in place in 2018 including measures for electric vehicle adoption. These included electric vehicle share targets as formulated by the city of Vienna where at least 10% of car trips in the city should be electrified in 2025 (Magistrat der Stadt Wien, 2016). Hamburg wants to increase the proportion of vehicles with zero emissions to 5% by 2020 or 25% of new vehicles registered annually by 2030 (Bürgerschaft der freien und Hansestadt Hamburg, 2015). Amsterdam and Berlin set more qualitative targets such as remaining the frontrunner or becoming an example city of electromobility (City of Amsterdam, 2015; Berliner Agentur für Elektromobilität eMO, 2014). Strategic targets for allowing only electric vehicles to access city areas were set in 2018 by Oslo for 2024, Paris and Stockholm for 2030, and Brussels for 2035 (City of Oslo, 2016; City of Paris, 2018; WSP Sverige AB, 2018; Brussels Environment, n.d.). To reach these electric vehicle goals, the cities list a variety of policy measures in their relevant strategies and programs. Key policies include preferential access to restricted city zones, the electrification of shared fleets, public procurement of electric vehicles, the extension of the public charger network, and information and awareness-raising campaigns.

Public electric vehicle procurement. Public procurement programs to stimulate demand for electric vehicles are a key measure among European markets. All metropolitan areas have adopted local requirements or base their tendering processes for the purchase or lease of vehicles on national frameworks, usually defining certain standards for the procurement of vehicles in public bodies and the preferential purchase or lease of electric vehicles. Some local governments have also specifically formulated procurement targets for electric cars. In the Brussels metropolitan area, since 2015, regional authorities that buy or lease new cars must integrate at least 25% of electric cars into their fleet in a 3-year period, or 15% in the case of local authorities; the rate is likely to increase to 40% or 25% from 2020 (Brussels Environment, 2018). In Madrid, the city council's aim is to have 90% of the municipal fleet of vehicles less than 3,500 kg being BEVs, PHEVs, or hybrid electric vehicles (HEVs) by 2030 (Madrid City Council, 2018a).

Electric vehicle information and awareness raising. Addressing potential lack of information and awareness is a measure widely adopted among European markets. All cities provided at a minimum information on their city authority's websites. Topics ranged from incentives for purchasing electric vehicles, parking, or charging benefits to information about the public charger network. In Berlin, the Senate set up the Berlin

Agency for Electric Mobility (eMO) in 2010 to act as the central point of contact and coordination for electromobility in the metropolitan area. The homepage includes information about subsidies, funding programs, projects, and events (Berliner Agentur für Elektromobilität eMO, 2019). Amsterdam set up an Electric Mobility Information Centre located in the city to inform stakeholders in the metropolitan area about electric mobility (e-mobility-nsr, 2017). Madrid carries out a yearly exhibition providing test rides with electric vehicles aimed at Madrid's citizens (Ecomotion, 2018). In 2018, Helsinki was the starting point of a two-week race for electric cars through 10 countries with the goals of raising awareness and emphasizing that electric cars are well suited for long journeys (City of Helsinki, 2018b).

SUMMARY

The description of selected national and local policies to support electric vehicle uptake focusing on 15 European markets demonstrates the complexity of different approaches and stakeholders being involved. Figure 3 summarizes promotion actions in 2018 in place at least half a year in the selected metropolitan areas. As shown across the top, there are 20 total potential actions (including vehicle incentives, charging infrastructure, and strategies, procurement, or information and awareness-raising activities) that were in place for at least one of the 15 metropolitan areas. The metropolitan areas are listed down the first column in order of how many total actions were adopted in the area. In general, all metropolitan areas with the exception of Copenhagen and Zurich had implemented a broad mix of policy measures including at least 12 out of the 20, in 2018. London had applied the most promotion actions in 2018, with 17, including benefits for electric vehicle purchase and operation, benefits for the extension of the recharging infrastructure, electric vehicle strategies, electric vehicles in municipal fleet operations, and information and public awareness-raising campaigns. Oslo and Stockholm ranked second with 15 actions, also applying a broad mix of policies addressing affordability, convenience, and information likewise.

National-level programs that provide tax benefits or financial incentives for owning a BEV, for the private use of an electric company car, and the installation of the public charging infrastructure were the most commonly adopted actions. Financial purchase and use incentives, as previously described, took on many forms, including one-time and annual taxation and registration discounts. Among the less favorable national policies were one-time grants for PHEVs, as some governments increasingly focus more on BEVs.

At the local level, the integration of electric vehicles in public vehicle fleets and providing information about electric vehicles were common promotion actions in 2018. Other similarly popular local actions were setting strategic goals for the uptake of electric vehicles and providing on-street public charging infrastructure. Although less common, several cities have also supported public, home, and workplace charging installations and offered benefits for parking, charging, or the use of road infrastructure and access to certain areas of the city.

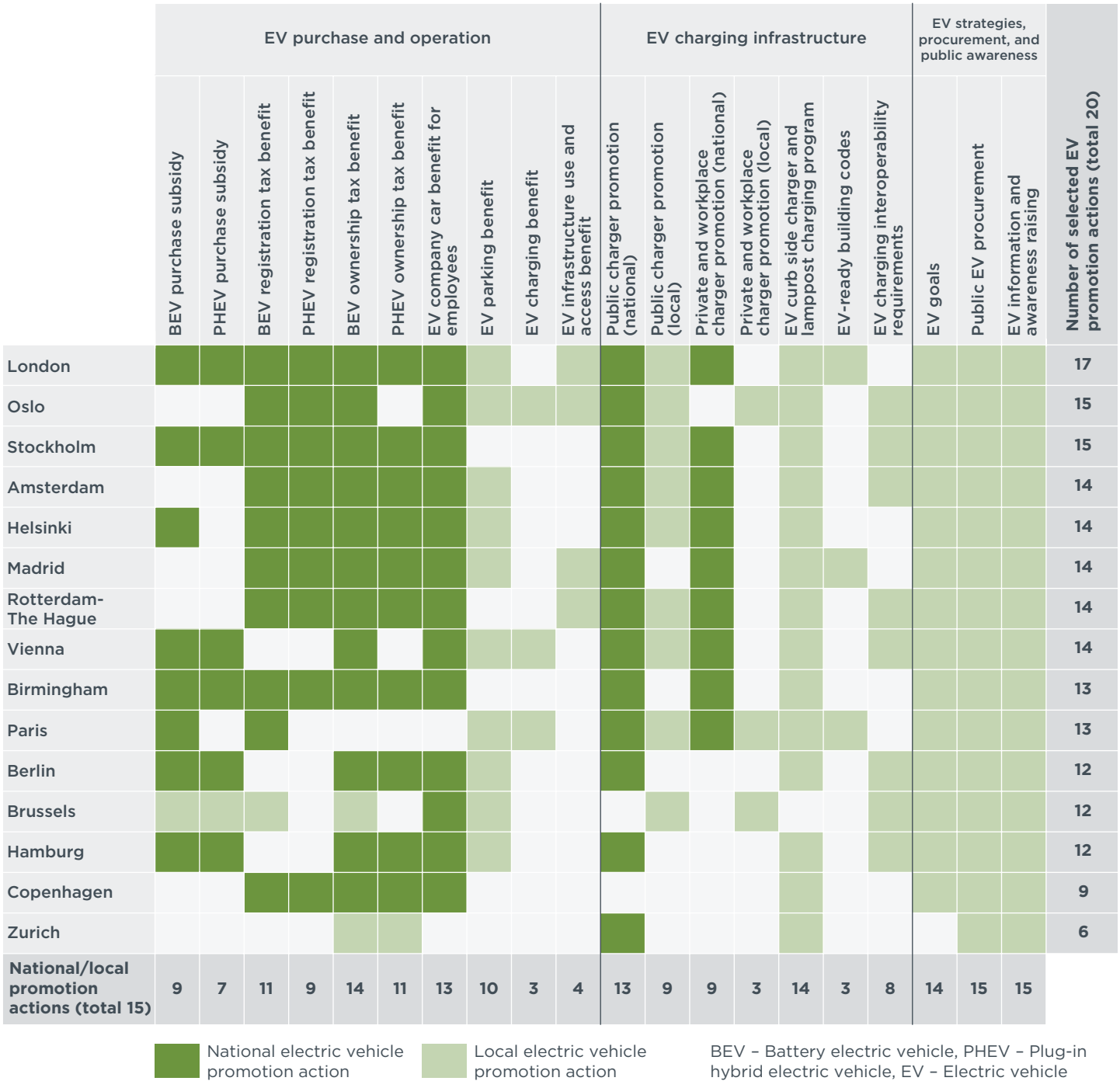

Figure 3. Electric vehicle promotion actions applied in 2018 for at least six months in selected European metropolitan areas.

ANALYSIS OF ELECTRIC VEHICLE METRICS

To assess local-level electric vehicle uptake and compare the relative strength of various initiatives in supporting electric vehicle uptake, we catalogue and analyze available market and policy metrics. After introducing the electric vehicle uptake data, we quantify representative vehicle taxation for private ownership and business uses, analyze charging infrastructure, and assess model availability in relation to electric vehicle sales shares.

ELECTRIC VEHICLE UPTAKE

For this assessment of local-level electric vehicle uptake, data on new passenger car registrations are analyzed from Dansk Elbil Alliance (Personal communication, July 22, 2019), Dirección General de Tráfico (2019), IHS Markit (2019), and Ministère de la Transition Écologique et Solidaire (2019). The datasets include local-level data across the major national Europe electric markets. The analysis focuses on the 200 metropolitan areas with more than 250,000 inhabitants in 2018, and especially the 15 selected areas with high electric vehicle share and sales in 2018, and diverse electric vehicle support activities. The selected areas tend to be the markets with the highest electric vehicle uptake within each of top national European markets (as shown in Figure 1).

Figure 4 illustrates electric vehicle share of new passenger car registrations in 200 metropolitan areas with more than 250,000 inhabitants in 2018, highlighting the 15 areas of our analysis. The figure shows that, in 2018, electric vehicle uptake differed considerably across countries and metropolitan areas. Electric shares were particularly high in Norway, with Oslo at 61% and Bergen at 64%. Several Swedish markets also had high electric uptake, including Stockholm at 13%, Gothenburg at 6.5%, Uppsala at 7.6%, and Malmö at 7.2%. Shares in the Netherlands areas included Amsterdam at 7.2%, Utrecht at 6.1%, Rotterdam-The Hague at 5.5%, and Breda at 7.9%, all of which saw almost far more BEV than PHEV sales in 2018. Other relatively high markets include Helsinki with 6% in Finland; Birmingham at 5.1% and London at 2.8% in the United Kingdom; Antwerp at 2.9% and Gent at 3.9% in Belgium; and Zurich at 3.7% and Geneva at 3.1% in Switzerland. The overall average electric share for Europe (the EU and EFTA) in 2018 was 2.5%, including all the markets shown in Figure 1.

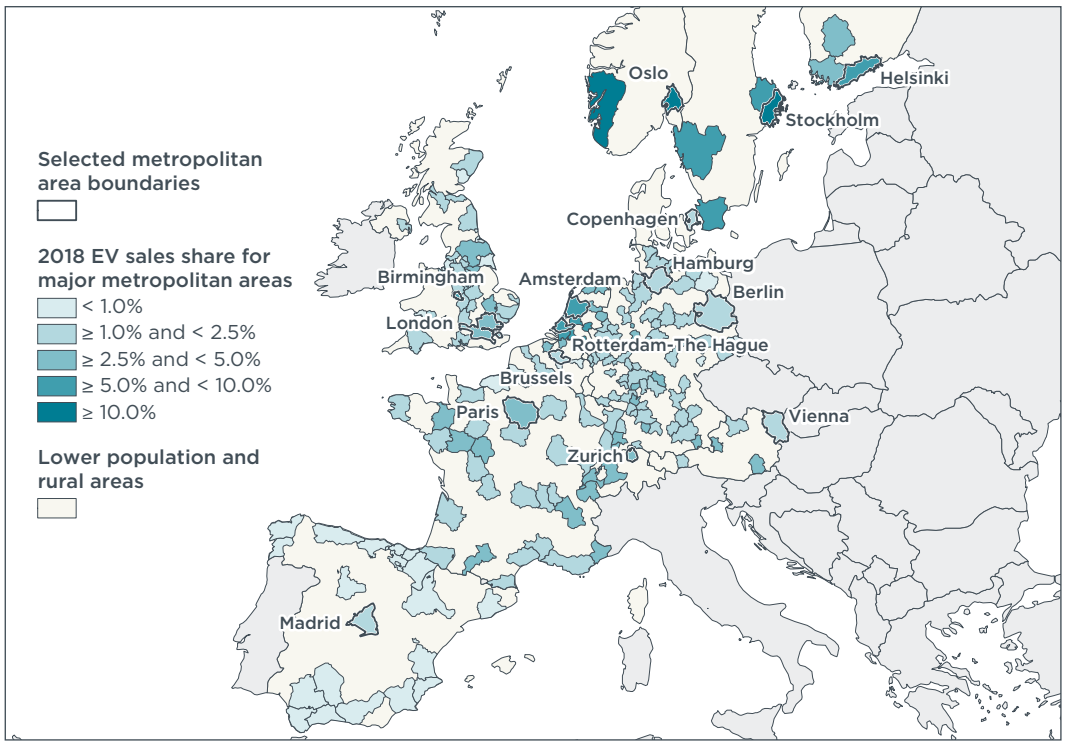

Figure 4. Electric vehicle share of new registrations in major European metropolitan areas.

These data reveal some additional insights regarding electric vehicle uptake across Europe. First, the capital regions generally lead their respective countries in electric vehicle sales shares; in some cases, the capital regions have much higher uptake than the national average (e.g., Madrid at 1.7% versus Spain at 0.8%; Stockholm at 13% versus Sweden at 7%). Out of these 12 countries, there was only one where the capital had lower uptake than the country as a whole: Vienna at 2.4%, versus Austria at 2.5%. Some of these countries are much more homogenous in terms of electric vehicle uptake than others. In France, half of the metropolitan regions fell between 1.8% and 2.5%, with the highest metro area having only 3.1% share. In Spain, half of metropolitan regions had uptake between 0.3% and 0.5%. In the United Kingdom, however, the regional differences were much greater: The highest metropolitan region (Birmingham) had a 5.1% sales share, the lowest 0.6%, and the interquartile range a comparatively wide 1.2% to 2.2%. The tax structures, subsidies, company vehicle policy, infrastructure, and model availability which influence electric vehicle uptake in each of these regions are analyzed below.

SUBSIDIES AND TAXES

Subsidies and taxes can play an important role stimulating electric vehicle sales (Wappelhorst, Mock, & Yang, 2018). Due to different regulations for cars in private and company ownership and operation as well as the importance of vehicle sales in the company segment, we analyze the effects on electric vehicle uptake separately.

Vehicles operated on a private basis

Promotion actions, subsidies, and tax liabilities for electric vehicles are intended to reduce their total vehicle costs compared to a conventional car. To evaluate the actual cost implications on electric vehicle uptake, the 4-year ownership costs of a BEV and PHEV versus a gasoline car purchased and operated on a private basis are compared. For the analysis, different Volkswagen (VW) Golf models as the top-selling passenger car in Europe are chosen (Mock, 2018) as shown in Table 3. In line with similar studies, the manufacturer's officially disclosed purchase price in each market is used before the application of initial one-time subsidies (Wappelhorst, Mock, and Yang, 2018; Volkswagen, 2019). Vehicle configurations are based on the BEV VW e-Golf and PHEV VW Golf GTE. For the gasoline VW Golf, average vehicle configurations are used and matched with the model that best reflects the specifications. CO_2 emissions reflect data on the New European Driving Cycle (NEDC).

Table 3. VW Golf variants selected for the analysis.

Model	Powertrain	Engine power (kW)	CO_2 emissions (g/km)	Engine size (cm^3)
VW Golf 1.5 TSI	Gasoline	92	120	1,395
VW e-Golf	BEV	100	0	-
VW Golf GTE	PHEV gasoline	110	37	1,395

In addition to the vehicle purchase price, we consider Value Added Tax (VAT), which is applied to the vehicle's base price on car purchase, and one-time registration tax on acquisition. Periodic taxes for owning a vehicle are projected at yearly intervals. Any one-time subsidies for private households provided by national government are also taken into account. In Germany and Austria, the grants provided by the industry in addition to the governmental contribution are factored in as well. An amortization period of 4 years and a discount rate of 6% are used in line with previous studies. The analysis is based on tax data for the 2018 financial year and takes into account changes in vehicle taxation and subsidy policy during the year. Further costs, such as expenses for insurance, repairs, extra fees, registration fees, or maintenance as well as total fuel costs are not included, as the focus is on the impact of purchase and ownership taxation only.

Figure 5 plots national vehicle taxes and one-time bonus payments for BEVs (left) and PHEVs (right) in the markets selected for the analysis over a 4-year period. In the Netherlands, ownership tax also includes a regional tax component. Cost differences on registration and ownership tax are derived through the delta between the electric VW Golf versions and gasoline VW Golf. The order of cities is based on highest to lowest the 4-year BEV total cost difference. The analysis shows that in general, most governments provided higher incentives for BEVs than PHEVs in 2018.

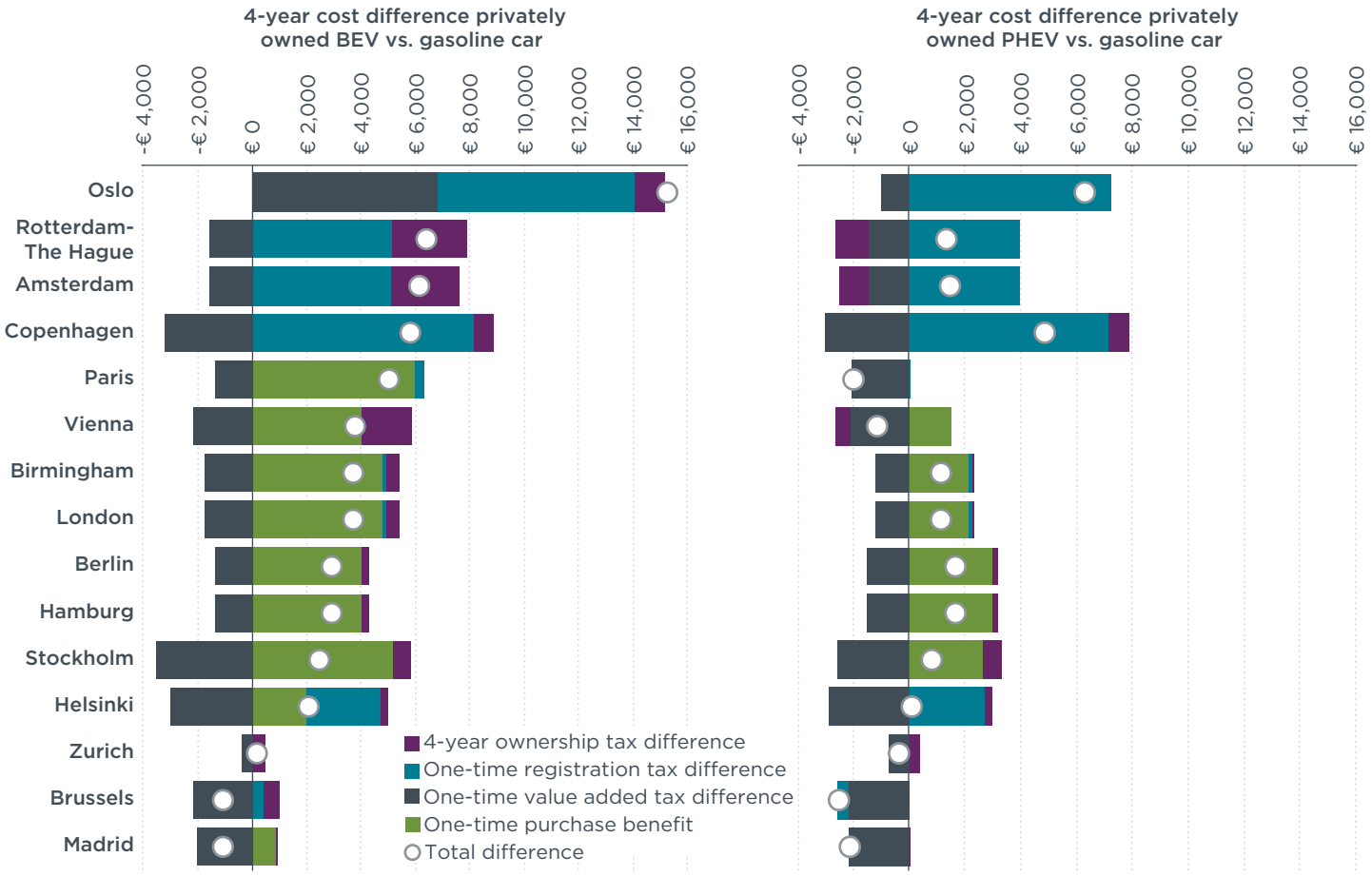

Figure 5. Four-year tax difference between a BEV and gasoline VW Golf (left) and a PHEV and gasoline VW Golf (right).

The incentive values varied widely across these 15 cities in 2018. The cost benefits for an electric vehicle compared to a gasoline car were the highest in Oslo, particularly for BEVs as the government waives 25% VAT at car purchase and grants discounts on registration tax. In Rotterdam-The Hague, Amsterdam, and Copenhagen, the cost benefits were also a result of preferential national taxes on registration. Purchasers of a vehicle in Paris, Vienna, Birmingham, London, Berlin, Hamburg, Stockholm, and Helsinki profited from national one-time bonus payments in the absence of equally significant tax advantages on registration tax. In Zurich, Brussels, and Madrid, the national or regional governments provided no strong incentives for electric vehicles on car purchase and ownership in 2018, resulting in total 4-year marginal cost advantages or cost disadvantages for the electric VW Golf compared to the gasoline variant.

Figure 6 plots the total 4-year tax benefit as a function of 2018 BEV (left) and PHEV sales shares (right). The results indicate that significant cost advantages for a BEV compared to a gasoline car can result in significant BEV uptake, most pronounced in Oslo with a 2018 sales share of 43% and a 4-year cost advantage of about €15,000 on car purchase. Rotterdam-The Hague and Amsterdam also experienced a high BEV

uptake in 2018, 4.6% and 6.5% respectively. Here, 4-year cost benefits added up to more than €6,000. In contrast, the owner of a BEV in Madrid or Brussels settled at about €2,000 or €1,100 higher 4-year taxes than the owner of a gasoline car living in the same metropolitan area. At the same time, BEV market shares were one of the lowest in 2018, 0.8% and 0.6% respectively.

If comparing the PHEV VW Golf GTE to a VW Golf gasoline, there is no clear correlation between electric vehicle sales shares and cost differences. Oslo, for example, experienced a high PHEV uptake (18%) and provided a significant 4-year tax advantage of more than €6,000. In markets with PHEV sales less than 1% (Madrid, Hamburg, Vienna, Paris, Amsterdam, and Rotterdam-The Hague) the tax difference ranged between a cost disadvantage of more than €2,000 (Madrid) and an advantage of €3,000 (Paris) over a 4-year holding period. While in some of these markets tax disadvantages for a PHEV resulted in low uptakes, other markets—Paris, for example—experienced similarly low sales (1%) despite a significant tax benefit. Also, in the case of Stockholm, despite low tax advantages for private owners of PHEVs, the metropolitan area recorded one of the highest PHEV sales in 2018 (11%), which can be partly explained by the tax advantages for company owned cars.

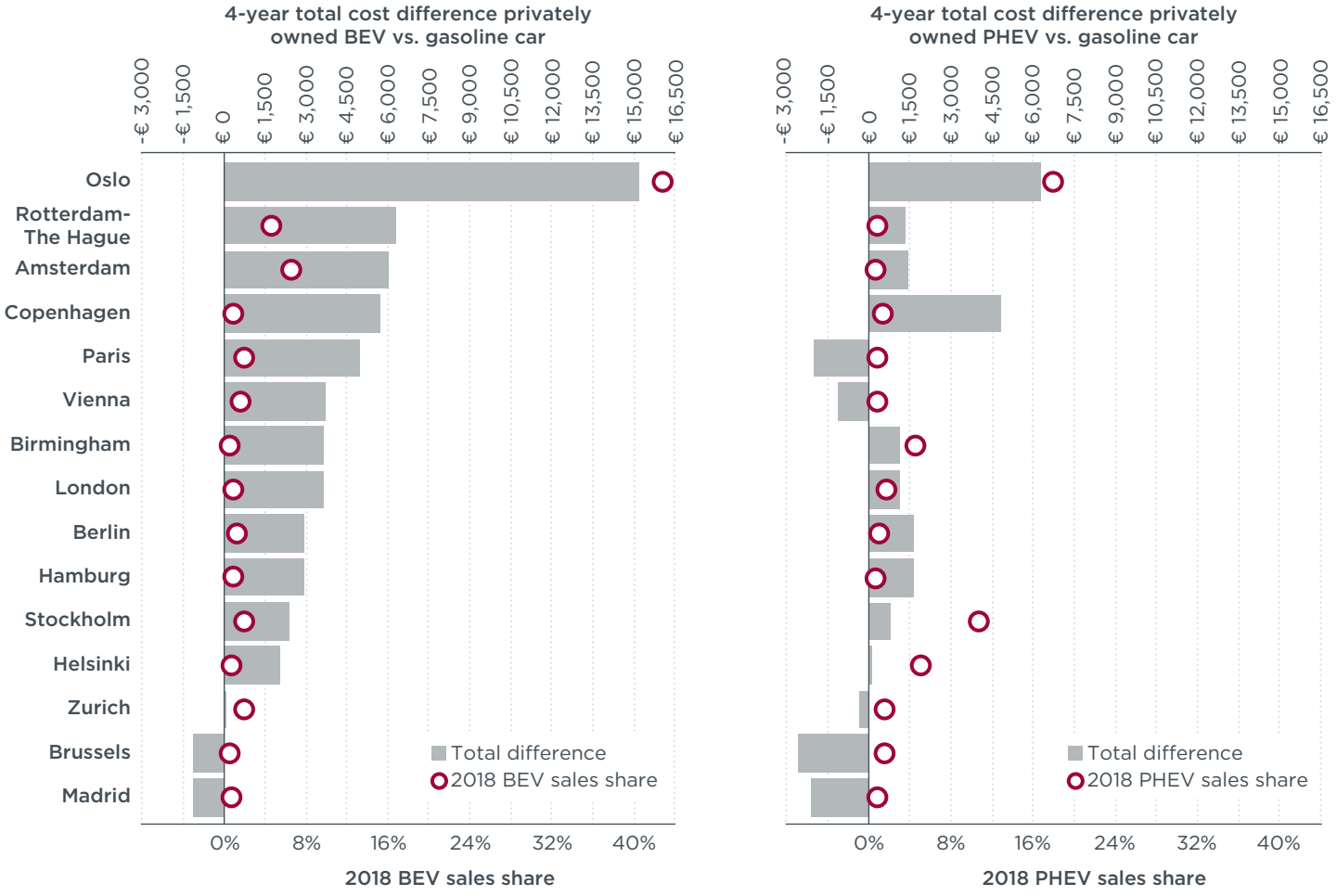

Figure 6. Four-year cost difference comparing BEV over gasoline VW Golf (left) and PHEV over gasoline VW Golf (right) in relation to 2018 BEV and PHEV sales shares in selected European markets.

There are also examples of low electric vehicle uptake despite significant tax advantages in 2018, pointing to the importance of durability and transparency in incentive design while also adopting a full suite of supporting policies. Copenhagen provides an illustrative example: The 2018 BEV sales share in that metropolitan area was 1% despite a significant tax advantage of almost €6,000 for the VW e-Golf

compared to the gasoline variant. In the past, electric vehicles were fully exempt from registration tax, an incentive that was gradually phased out starting 2016. In addition, incentives for electric vehicles have been adopted in irregular intervals, which may have created uncertainly among potential electric vehicle buyers and also discouraged auto dealers from promoting electric vehicles. Additionally, the structure of incentives in Denmark means that the price difference is less stark for the small city cars which are most popular in Copenhagen, making these incentives less valuable for many prospective car buyers. All of these factors might have created uncertainties, making consumers less enthusiastic about purchasing an electric car. Likewise, Spain nominally offered incentives of €5,500 for a new BEV, but the incentive funding was exhausted in only a few days in the end of 2017, making the program far less useful for consumers purchasing an electric vehicle in 2018.

By contrast, the markets with the highest electric vehicle sales shares in 2018 not only had large financial benefits in place this year, but also long track records of promoting electric vehicles. Norway has promoted electric vehicles through its VAT exemption since 2001. The Netherlands has also offered electric vehicle incentives for many years, although it shifted its policies in 2016 to promote BEVs rather than PHEVs, and subsequently saw a market shift from PHEV-dominated to BEV-dominated. Although Sweden in the past has struggled with inconsistent funding for incentives, the country's bonus-malus system adopted in 2018 was designed with reliability and transparency in mind, resulting in steadier electric vehicle sales and one of the highest market shares in Europe (Wappelhorst & Tietge, 2018).

Vehicles owned by companies

A large share of passenger vehicles in Europe are owned by companies and partly also provided for the private use of employees. Therefore, taxation policies and the impact on the costs of an electric company car privately used by an employee is also evaluated. For the assessment of the company car benefit for an employee the analysis is conducted similar to that of private owners. In contrast to private ownership, a shorter, 3-year holding period is assumed, reflecting average holding periods of company cars (Wappelhorst, Mock, & Yang, 2018). As the tax for the private use of a company car also depends on the earnings of an employee, high income employees (gross yearly income of at least €90,000) are assumed who are more likely to benefit from a company car, and consequently, are paying the highest taxable rates on income tax (assuming marginal tax rate). Furthermore, it is assumed that additional costs such as fuel are either paid by the employer or, in case of private use, are not part of the employee's tax liability.

Figure 7 shows the 3-year tax gap between the exemplary VW e-Golf and VW Golf gasoline and the BEV sales share in 2018 (left) and the same comparison for a PHEV VW Golf (right). The total BEV or PHEV sales are plotted rather than only company car-related BEV or PHEV sales in Figure 7 because of the shortage of data.

The analysis shows higher cost gap variations for BEVs than for PHEVs, reflecting higher tax advantages for zero-emission company cars. BEV sales shares tend to be particularly high in those markets that also provide significant tax advantages for a battery electric company car compared to a conventional car. In the Netherlands, the 3-year tax advantage added up to almost €7,800; in Norway it came to €5,400 for the tax year 2018. At the same time, BEV shares were the highest at 43% (Oslo), 6.5% (Amsterdam), and 4.6% (Rotterdam-The Hague). On the contrary, there were markets with lower sales shares, e.g. Austria with 2018 BEV sales shares of 1.6% despite a tax benefit of more than €6,600.

In markets with high PHEV shares such as London (1.8%), Birmingham (4.6%) and Stockholm (11%), employees also benefited from tax advantages for plug-in hybrid company cars over a 3-year period compared to a conventional gasoline VW Golf,

whereas in all other markets PHEVs experienced higher taxes. As for PHEVs operated on a private basis, there are no clear correlations between cost benefit and PHEV sales shares if comparing all metropolitan areas.

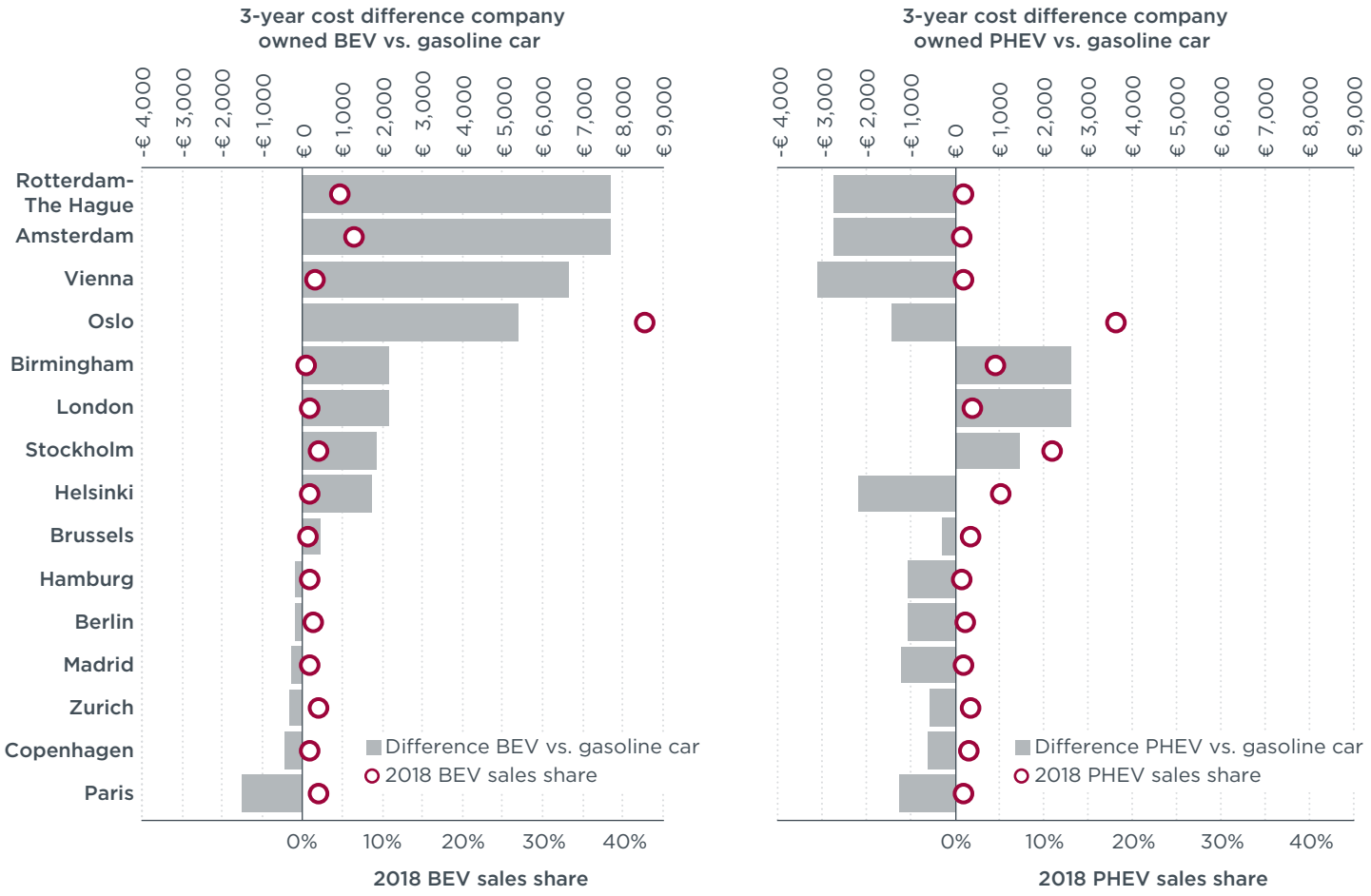

Figure 7. Three-year cost difference between a BEV or PHEV and gasoline VW Golf in relation to 2018 BEV or PHEV passenger car sales in selected European cities.

The results on subsidies and taxes show that significant incentives and tax benefits on car purchase, ownership, and use can be an important policy to stimulate electric vehicle sales in some markets. However, for other markets with a much slower uptake despite notable benefits, other policies might have a more significant effect. Distilling a general trend is difficult also because of not having private versus company car data.

In addition to the taxes analyzed, further costs such as operating costs or costs for the use of road infrastructure add to the total cost of ownership. However, these costs have not been analyzed as part of the study. A previous study shows that relatively high gasoline and comparatively low electricity prices (e.g., in Norway and the Netherlands) can correlate positively with electric vehicle sales, whereas a lower cost delta (e.g., in Germany) can slow their market entry. Savings on national and local road charges can add to the cost benefit. In London, for example, the 4-year cost savings for drivers of an electric vehicle can be as high as €10,000 compared to the driver of a conventional car (Wappelhorst, Mock, & Yang, 2018).

CHARGING INFRASTRUCTURE

A key policy to stimulate electric vehicle growth can also include the installation of sufficient charging infrastructure (Slowik & Lutsey, 2018; Slowik & Lutsey, 2019; Nicholas & Hall, 2018; Hall, Cui, & Lutsey, 2019). To show how public charging infrastructure has helped electric passenger vehicle uptake, the number of public

charge points per population (in millions) are plotted—differentiated by normal (typically defined from underlying data as 3.7 to 22 kilowatt power capacity) and fast charge points (over 22 kilowatt)—against the share of 2018 new electric passenger car registrations (see Figure 8). The figure shows some large variation between uptake and charging availability indicating that other factors are needed to fully explain the relationship between public charging and vehicle sales in any one year. Nevertheless, markets with a high density of public charge points tended to have a higher share of electric vehicle sales. For example, Oslo, Rotterdam-The Hague, and Amsterdam had more than 2,500 charge points per million population and high electric vehicle sales in 2018, ranging between 5.5% (Rotterdam-The Hague) and 61% (Oslo). On the contrary, a significantly smaller share of public charger infrastructure as observed in Helsinki and Birmingham did not discourage consumers from buying electric vehicles.

Differentiated by normal and fast charge points, Oslo and Rotterdam-The Hague had the most normal charge points per population in 2018 with 3,000, followed by Amsterdam (over 2,700). Oslo also had the highest concentration of fast charge points per capita (over 300), followed by Zurich (over 100), and Hamburg and Paris (over 80 each). With a few exceptions, most notably Hamburg, the cities with a higher density of charging infrastructure have a higher-than-average electric vehicle market share. In Madrid, the lack of charging infrastructure plus unstable incentive policy as previously described might have slowed electric vehicle uptake compared to the other markets.

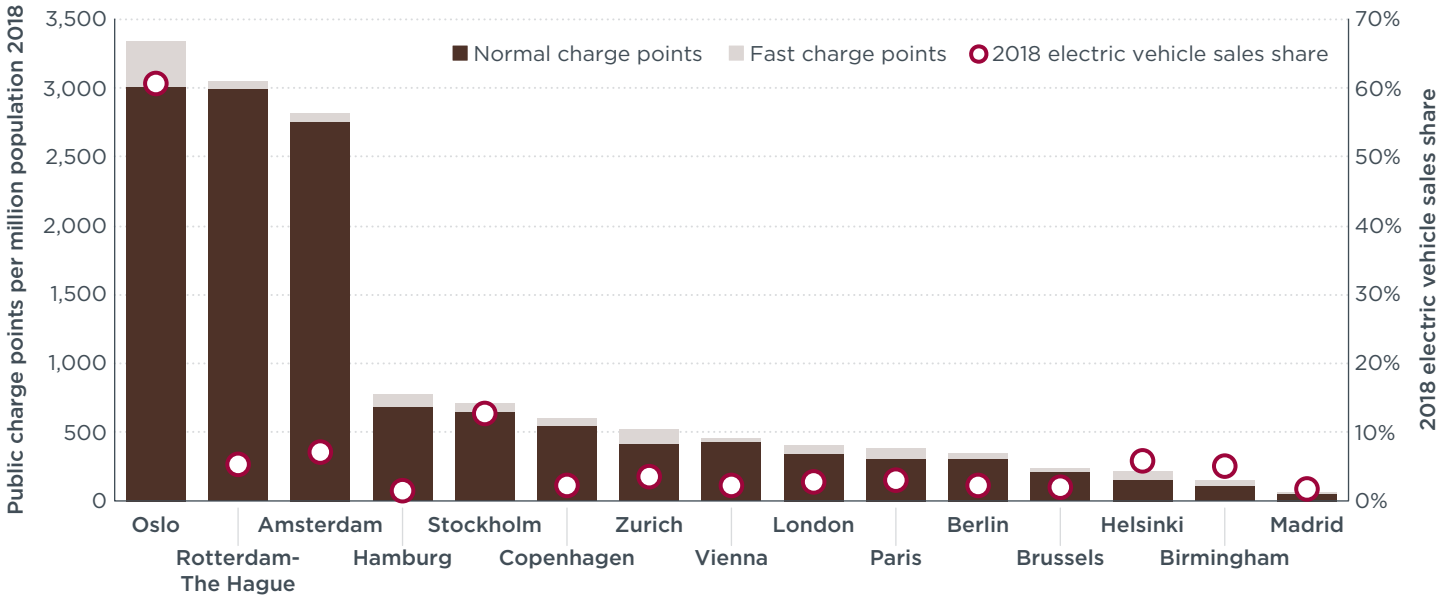

Figure 8. Public charge points per million population and electric passenger car sales in 2018.

As electric vehicle uptake and charging infrastructure continue to expand, continued examination of the appropriate ratio between electric vehicles and public charge points is a key question. The European Commission recommends 10 electric vehicles per charge point. While this is reasonable overall guidance at this early stage in the market, there are good reasons for variation across markets due in part to the greatly differing availability of home charging. In Oslo, on average there were approximately 26 electric vehicles per public charge point; each public charge point supported half as many vehicles in Zurich. Rotterdam-The Hague had the lowest average ratio with one public charge point for every two electric cars; Amsterdam, Berlin, Copenhagen, Hamburg, London, and Vienna also had low ratios ranging from 3 to 8. In Birmingham the ratio was the highest with 48 electric vehicles for each public charge point, followed by Madrid (39).

MODEL AVAILABILITY

A certain number of electric vehicles on the market is necessary to create a demand. National or local governments can only indirectly regulate their market entry. Rather, electric vehicle provision by manufacturers is largely driven by national or transnational vehicle standards and the development in non-European electric vehicle markets. Here, the number of unique electric vehicle models available in each metropolitan area are considered, with a model counted if it had at least 20 registrations in 2018.

In 2018, model availability increased to more than 40 in some European markets. Figure 9 illustrates the availability of electric vehicle models in the markets selected for the analysis and compares this to the electric vehicle sales shares. Consumers in these markets could select from between 17 and 43 different electric vehicle models in 2018, the majority being PHEVs (from 7 to 27). BEV model availability ranged between 6 and 19. Only in the Netherlands did BEVs dominate electric vehicle model availability.

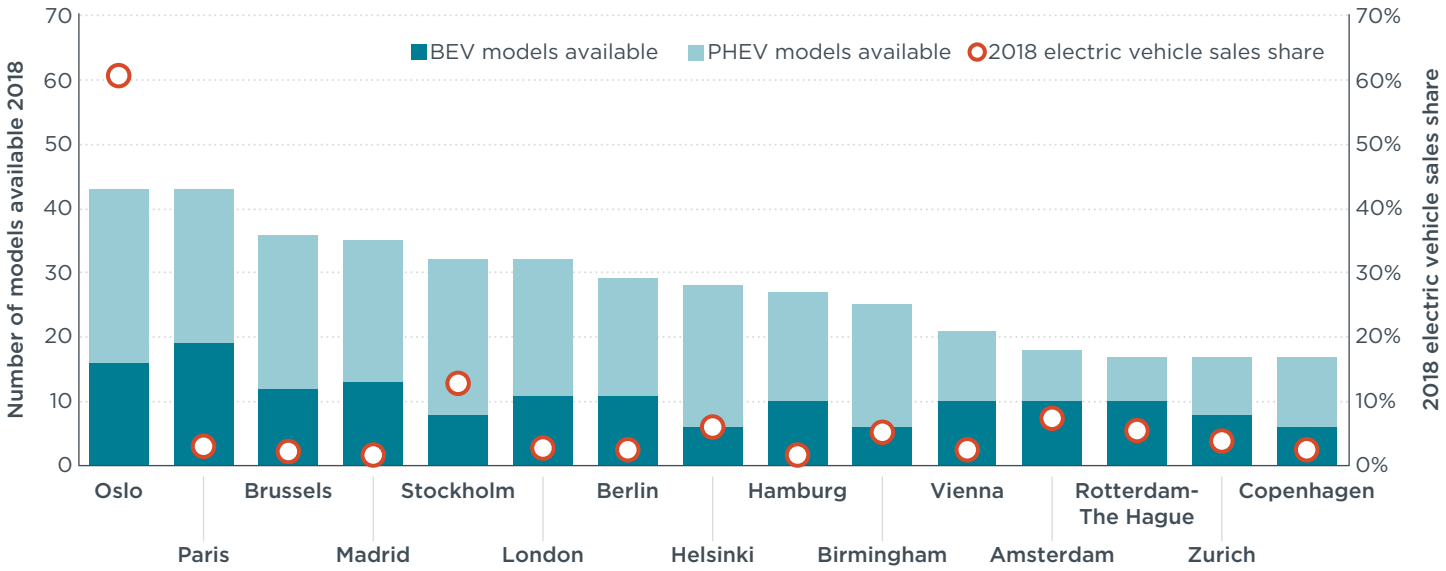

Figure 9. Model availability of electric vehicles and share of electric passenger car sales in 2018.

The figure reveals that consumer behavior can be explained only partially by model availability. In general, high model availability does not necessarily lead to higher electric vehicle uptake. In Madrid, despite more than 30 electric vehicle models being available on the market, electric vehicle sales were less than 2%. Similarly, for Hamburg electric vehicle sales were as low as 1.7% although consumers could select between more than 25 different electric vehicle models. On the contrary, markets such as Amsterdam and Rotterdam-The Hague experienced a high electric vehicle uptake even though fewer than 20 models were available.

As all of the metropolitan areas here had higher electric vehicle uptake than the European average, this could be an indication that there was enough diversity of models to satisfy demand in the passenger car segment. However, a lack of models for certain vehicle segments, use cases, or brands, such as vans for commercial use or larger private vehicle segments, or long delivery times could obstruct faster market growth and partially explain why some markets experienced higher sales shares in 2018 compared to others.

SUMMARY

Figure 10 gives an overview of selected policies in relation to electric vehicle sales in 2018. Even though a clear trend is not evident, some markets with significant tax breaks on car purchase, an extensive charging network, a sufficient number of electric vehicle models, and a variety of promotion actions at local and national levels show higher electric vehicle sales (e.g., Oslo, Amsterdam, Rotterdam-The Hague). On the contrary, there are markets like Zurich with comparably high uptakes despite the lack of significant financial benefits, charging infrastructure, model availability, or number of promotion actions in place. In addition to the policies analyzed as part of this paper, many more factors are likely to influence electric vehicle sales shares such as other cost aspects (fuel versus electricity costs, insurance costs, maintenance costs), and sociodemographic parameters such as social status or income.

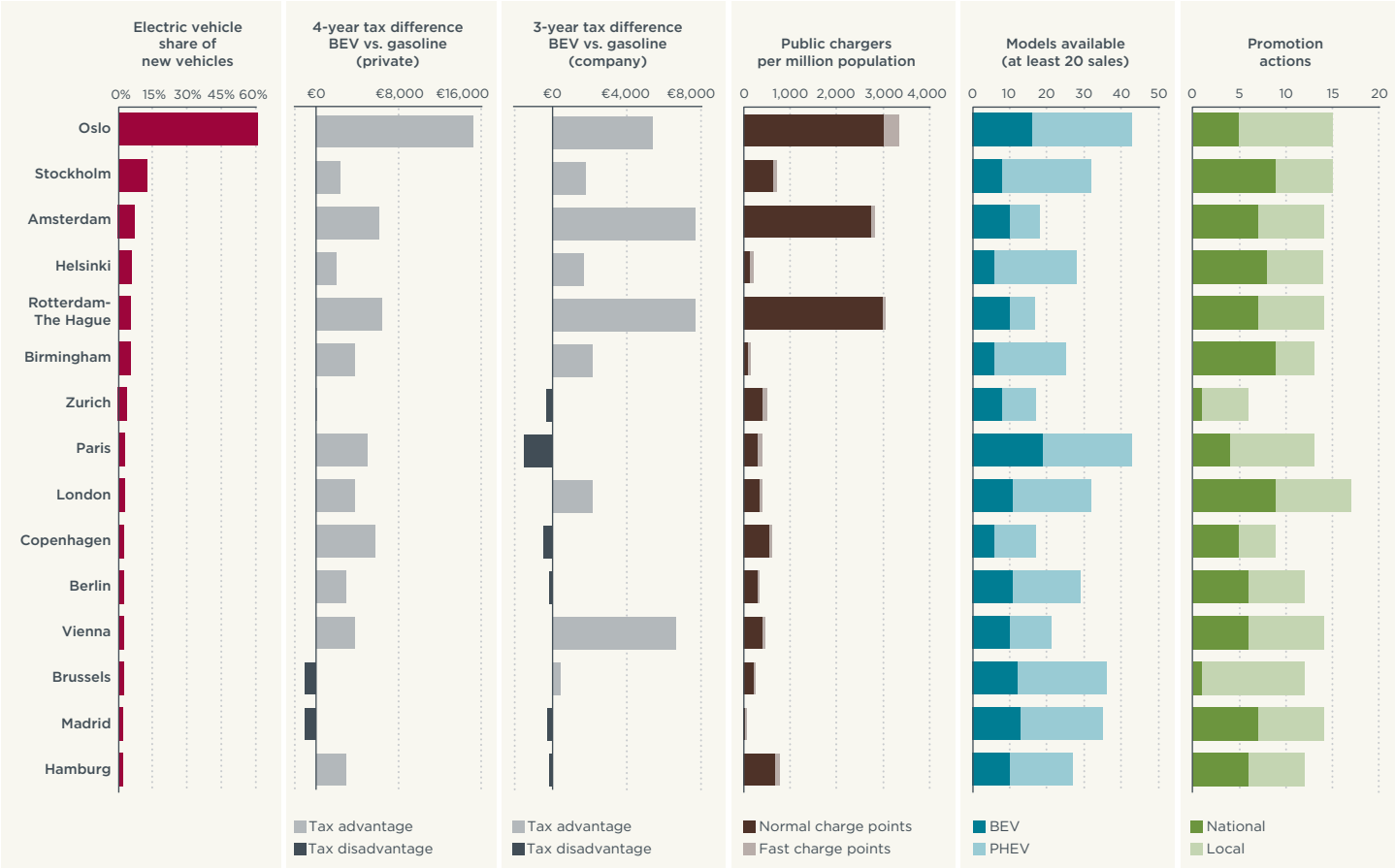

Figure 10. Overview of 2018 electric vehicle sales and selected policies.

Based on this analysis, the following paragraphs summarize key actions that have been taken in the metropolitan areas selected in this report. All selected areas tend to be the markets with the highest electric vehicle uptake within each of the top national European markets, and at the same time apply mostly a broad mix of measures analyzed as part of this study.

Oslo. With 61% of all new vehicles being electric in 2018, Oslo remains one of the leading cities worldwide in electrifying its local vehicle fleet. This electric vehicle share is 13% greater than Norway's already world-leading 54% sales share in 2018. Oslo had 3,334 public charge points per million people, a rate that is more than 50% higher than the Norwegian average and almost 11 times the average for all of Europe.

Significant tax breaks on car purchase exempting battery electric vehicles from 25% VAT and registration tax are strong policies helping to break the cost barrier between

electric and conventional vehicles in Norway. The extensive expansion of the public charging infrastructure network and waivers on national road tolls, coupled with local incentives such as the use of bus lanes, parking benefits, and exemptions on congestion charges, have helped to overcome the key barriers of cost and convenience and spur the demand for electric cars in Oslo. The existing policies—for example, significant tax breaks of several thousand euros on car purchase, the highest density of public normal and fast charge points per million population, and having more than 40 electric vehicle models available for purchase—have ensured that Oslo remains one of the leading electric vehicle cities worldwide.

Stockholm. The metropolitan area's electric vehicle market has grown significantly in 2018 to 12.7% from 8% a year earlier. Stockholm's electric vehicle share was 75% higher than the average uptake of 7.2% in Sweden. In terms of infrastructure, Stockholm's rate of 717 charge points per million people was in line with the Swedish average, but 3.3 times the European average.

At the national level, Sweden introduced a bonus-malus tax scheme part way through 2018, providing even higher incentives for the acquisition of an electric vehicle prior to its introduction. The months following the redesign of the vehicle tax system experienced high, sustained shares of electric vehicle sales (Wappelhorst & Tietge, 2018). Preferential tax breaks for cars in private and particularly company ownership have helped to spur electric vehicle uptake, particularly of PHEVs. At the local level, the city authority of Stockholm itself serves as an example in terms of vehicle environmental procurement of the municipal fleet with preference given to electric vehicles. Cooperatives with electricity companies to build up the public charging infrastructure network on land free of charge contributed to an increased consumer convenience when recharging their vehicles outside their home and workplace.

Amsterdam and Rotterdam-The Hague. Both cities have experienced high electric vehicle growth rates in 2018. Amsterdam had an electric vehicle sales share of 7.2% and Rotterdam-The Hague recorded 5.5%; these were 34% and 1% higher than the Netherlands sales share of 5.4%. Both of these cities had very high densities of public charge points. Amsterdam had 2,821 public charge points per million people, 30% higher than the Dutch average and 9.2 times the European average. Rotterdam-The Hague had slightly higher infrastructure availability at 3,042 charge points per million people, 40% higher than the Dutch average and 9.9 times the European average.

National policies including significant tax advantages for privately and company owned electric cars on purchase, particularly focused on the uptake of zero-emission vehicles, have been implemented to break down the initial higher purchase cost of an electric vehicle compared to a conventional car. The country's ambition to provide an extensive public charging infrastructure network, followed up by the Green Deal—an initiative by two Dutch ministries to further expand public charging options—has led to one of Europe's densest networks, nationally as well as in the immediate regions of Amsterdam and Rotterdam-The Hague. The interoperability of the public charging network guarantees user-friendly access to any driver of an electric vehicle. At the local level, public charging infrastructure is provided close to a consumer's home or workplace in case an electric vehicle owner cannot have a charging station on their property.

Helsinki. The metropolitan area's electric vehicle share reached 5.9% in 2018; this was 41% higher than Finland's overall electric vehicle sales share of 4.2%. Charging infrastructure in Helsinki stood at 221 public charge points per million people; this was 18% higher than the Finnish average, but 28% lower than the average rate across Europe.

The Finnish government introduced a one-time grant in the beginning of 2018 for the purchase or lease of a BEV. Nonetheless, 5.1% of all new vehicles sold in 2018 were PHEVs, which like BEVs benefited from significant tax breaks on registration

(3% of the vehicle's purchase price for a VW e-Golf and a VW Golf GTE versus 18% for the gasoline-powered Golf). The growth and expansion of the charging network was promoted in many ways in the country, including a national subsidy scheme for public and private charging stations aiming at companies, housing associations, and municipalities. In addition, electric vehicle drivers benefited from discounts on parking fees in Helsinki.

Birmingham. The metropolitan area experienced an electric vehicle uptake of 5.1% in 2018, mostly driven by PHEV sales (4.6%). This was the highest sales share in the United Kingdom and measured 2.3 times the national average of 2.2%. In terms of infrastructure deployment, however, Birmingham had only 53% of the United Kingdom average and 52% of the European average with its 160 charge points per million population.

Nationally, the British government provided one-time grants for the purchase of BEVs and PHEV; in October 2018, these were phased out for buyers of PHEVs. Employees also benefited from lower taxable rates on income tax if an electric company car was also used for private purposes, which might be one reason for the high share of PHEVs in Birmingham. The government was also investing heavily in the extension of the public charger network and provided special grants for home and workplace charging. At the local level, there were selective activities such providing information on the city council website focusing on electric charging facilities aiming at different user groups.

Zurich. The metropolitan area recorded a 3.7% sales share of passenger cars in 2018; this was 26% higher than the Swiss electric vehicle sales share of 2.9%. Public electric vehicle charging infrastructure in Zurich stood at 524 charge points per million population, which was 28% lower than the average rate in Switzerland but 71% higher than the average for all of Europe.

Compared to the other cities, the metropolitan area of Zurich had the fewest promotion actions in place. In addition, neither the Swiss government nor Zurich applied significant purchase or circulation tax advantages for electric vehicle buyers or owners, either in private or in business ownership. Up to 2018, there was also no significant activity in building up the public charging network. Still, Zurich had the second-highest share of fast charge points per million population across the 15 metropolitan areas. In addition, two Tesla models were among the four best-selling electric vehicles in Zurich in 2018, indicating that among other things, social aspects might have been a factor influencing the acceleration of the market.

Paris. Paris, with 3.0% of passenger car sales being electric in 2018, had a 41% higher sales share than France as a whole, at 2.1%. Additionally, the public infrastructure density of 390 charge points per million people was 5% higher than the French average and 27% higher than the European average.

The capital of France had several strong national and local policies in place to support the uptake of electric vehicles. Above all, France's bonus-malus vehicle tax system which offers purchasers of a zero-emission car a one-time bonus payment. Within the framework of the Advenir program, the French government has also made significant funding available for the extension of charging points, aimed at companies, public entities, and residential collectives. A national decree also formulates targets for the installation of charging infrastructure in parking lots. Furthermore, in Paris, electric vehicle drivers benefited from free parking and a flat rate for charging in 2018 and the Paris City Hall is taking a leading role in electrifying its municipal fleet, aiming at 90% of electric vehicles in their fleet by 2021.

London. Electric vehicle sales in London reached 2.8% in 2018. This was 26% higher than the 2.2% sales share recorded in the United Kingdom overall. There were 405

public charge points per million people in Greater London through 2018, which was one-third greater than the United Kingdom and European average.

Similar to Birmingham, electric vehicle drivers in London benefited from the national incentives on car purchase and grant schemes for the installation of charging points at home and at workplaces. At the city level, London's congestion charge for entering the city center is waived for vehicles emitting up to 75 g CO_2/km. In addition, some boroughs offered discounted or free parking and parking permits in 2018, reducing the costs for operating an electric vehicle. The Greater London Authority also aimed to substantially increase its own electric vehicle fleet and the city did heavily invest in the expansion of the public normal and fast charger network.

Copenhagen. 2.4% of passenger vehicles sold in 2018 in Copenhagen were electric, about 8% higher than the 2.2% sales share for Denmark. The public charging infrastructure availability in Copenhagen stood at 597 charge points per million population, 40% higher than the Danish average and almost twice the European average.

Even though on a national level registration tax benefits had been phased out for electric vehicles over the last few years, the 2018 registration tax rates were still significantly lower compared to conventional cars. Despite this advantage, the country experienced a significant drop in electric vehicle sales when phasing out vehicle tax breaks in 2016. At the local level, to increase the share of electric cars, one focus was the transition of municipal fleets in the metropolitan area toward electric vehicles. Also, to increase consumer convenience, the public charger network and curbside charging options have been extended in the past.

Berlin. Berlin had a share of 2.4% new electric passenger cars in 2018, which was 23% higher than the average 1.9% in Germany. The charging infrastructure network in Berlin measured at 345 public charge points per million people, 32% lower than the average in Germany but 13% higher than the average for all of Europe.

Purchasers of an electric vehicle in Germany benefited from a one-time subsidy and BEV owners from exemptions on the periodic ownership tax. Municipalities could apply for separate grants for the procurement of electric vehicles. The country is also heavily investing in the extension of the public charger network. At the local level, the city also allowed free time-limited parking during charging time. To inform about electromobility in the metropolitan area, the Senate of Berlin set up the Berlin Agency for Electric Mobility (eMO) in 2010, which serves as the central point of contact and coordination to help spur electric vehicle uptake in the city.

Vienna. The electric vehicle sales share in Vienna reached 2.4% in 2018, lagging slightly behind the Austrian national sales share of 2.5%. The public charging infrastructure concentration of 466 charge points per million people also lagged 29% behind the national average, but was still 52% higher than the average across all of Europe.

The Austrian government provided one-time grants for electric vehicles on car purchase and exemptions on ownership tax. Employees privately using a zero-emission company car did not have to pay for the benefit in kind on income tax unlike the use of a PHEV or combustion engine vehicle. In addition, companies and private households could apply for financial support for the installation of charging stations or wall boxes in 2018. Vienna also provided temporary free charging at charging stations in 2018.

Brussels. Sales of electric vehicles reached 2.2% in the Brussels metropolitan area in 2018, slightly higher than the 2.1% sales share of Belgium. Charging infrastructure in the Brussels area stood at a comparatively low 247 public charge points per million people, 24% higher than the Belgian average but 20% lower than the European average.

At the regional level, the regional government of Brussels did not offer special purchase incentives for private persons buying a BEV or PHEV in 2018; however, owners of a BEV benefited from lower rates on the periodic ownership tax compared to owners of a PHEV or conventional car. At the local level, businesses in the city of Brussels were offered tax exemptions when equipping their parking spaces for visitors or staff with a charge point. In terms of vehicle procurement, the regional and local authorities were obliged to integrate 25% or 15% of electric cars into their fleet on new car purchase or lease.

Madrid. Despite many promotion actions and a large number of electric vehicle models available, electric vehicle shares reached only 1.7% in 2018. Even though being among the lowerst of the sales shares in this study, this was more than twice the average 0.8% sales share in Spain. The public charge point availability of 60 charge points per million people, however, was 46% below the Spanish average and 80% below the European average.

In Spain, purchasers and owners of electric vehicles benefited from exemptions or reduced rates on registration tax and ownership tax in 2018. At the national level, there were building codes in place for the preinstallation of electric wiring for charging an electric vehicle and regulations for the procurement of electric vehicles in public fleets. At the local level, drivers of a zero-emission car could circulate and park for free in the city center of Madrid and electric vehicles could circulate along the high occupancy vehicle lanes. However, particularly national incentive programs for the purchase of an electric vehicle of the past have been complex and the funding for the one-time incentive on car purchase intended for the year 2018 ran out of funding within a short time when introduced at the end of 2017. Moreover, Madrid's charging network was not very dense, which among other factors might have obstructed a faster market entry of electric vehicles in Madrid compared to other markets.

Hamburg. Electric vehicles represented 1.7% of passenger vehicle sales in Hamburg in 2018, 14% below the German sales share of 1.9%. In contrast, charging infrastructure density was 53% above the German average and 2.5 times the European average at 781 public charge points per million people.

Complementing the national incentive programs—subsidies for electric vehicles and tax exemptions for BEVs on periodic ownership tax, as well as national schemes for the extension of the public charging network—the city of Hamburg applied exemptions on parking fees for electric vehicle drivers. Even though having the highest number of public charge points available in Germany, the lack of supporting policies in key areas (e.g., significant tax benefits at a national level, local private and workplace charging subsidies) and one of the fewest local actions compared to the other markets may have slowed the uptake of electric vehicle sales compared to other large cities in Germany.

CONCLUSIONS

The 15 metropolitan areas across 12 countries in Europe analyzed in this paper saw electric vehicle uptake ranging from 2% to more than 61% in 2018. Together, the different markets illustrate the impact promotion actions, incentives, charging infrastructure, and model availability can have on electric vehicle sales. Because of the multitude of electric vehicle barriers and complex market and policy drivers, there is no simple formula that explains the variance in electric vehicle uptake across European markets. Yet we can, based on the emerging data, conclude with the following recommendations to guide government actions to accelerate electric vehicle uptake.

Apply a comprehensive mix of electric vehicle promotion actions. Most high electric vehicle-uptake markets have adopted policies addressing the various prevailing consumer barriers of affordability, convenience, and awareness. London, Oslo, and Stockholm typify this broad approach, with at least 15 actions each (of 20 actions catalogued) across city and national levels. This research identifies the key action areas: financial incentives to bridge the cost gap between electric and conventional cars; programs to deploy charging infrastructure; and information campaigns to raise awareness and increase visibility regarding available electric vehicles and their benefits.

London, Oslo, and Stockholm have been among the metropolitan areas with the most promotion actions in 2018. Oslo and Stockholm experienced at the same time the highest electric vehicle sales shares, 61% and 13% respectively. On the contrary, despite many actions in place, London registered a much lower uptake of 3%. London had a less dense public charger network compared to the other two cities, which might have obstructed an even faster market growth. The analysis of selected policy measures such as vehicle taxes, public charging infrastructure, and model availability shows that one single policy can generally not explain electric vehicle market growth across markets. Rather, a comprehensive mix of promotion actions is crucial in the transformation to electric vehicles.

Introduce significant cost advantages for electric vehicles. Higher purchase costs for electric vehicles compared to combustion-powered vehicles remains a barrier for many consumers. National and local one-time purchase subsidies and annual national tax breaks on vehicle registration and operation are common where electric shares are high—for example in Amsterdam, Oslo, and The Hague. In contrast, markets which have largely not addressed cost barriers on car purchase or annual ownership tax (e.g., Brussels, Hamburg, Madrid) typically see slower electric uptake. Additional policies such as discounts or exemptions on parking fees or parking permits, electric vehicle charging, road tolls, and congestion charges can be powerful instruments at the local level to supplement national policies and provide further cost advantages for electric vehicle drivers.

This report shows that subsidy amounts and tax breaks adopted by the 15 markets vary significantly, which can affect electric vehicle uptake. For example, the 4-year cost gap between a BEV and a gasoline car in private ownership can range from a negative €1,000 (Madrid) to a positive €15,000 (Oslo) when considering one-time subsidies and taxes on vehicle registration and operation only. If privately using a company car, the 3-year cost gap varies from negative €1,500 (Paris) to a positive €7,700 (Amsterdam and Rotterdam-The Hague) for BEVs.

The positive effects of significant cost benefits for electric vehicles in both private and company operation are best reflected in Oslo. Private owners and employees privately using a battery electric company car benefit from savings of €15,000 and over €5,000 respectively. Local measures such as exemptions from congestion charges can also contribute to significant cost savings. In London for example, the

daily congestion charge of €13 is waived for vehicles emitting up to 75 g CO_2/km, which can add up to several thousand euros per year if the zone is entered regularly.

Support charging infrastructure to assure consumer convenience. Amsterdam, Oslo, Stockholm, and The Hague have built up dense networks of public charge points and experienced among the highest electric vehicle sales shares in the world. In addition, they have different local and national programs in place that support home and workplace charging. In markets such as Hamburg and Copenhagen with a dense network of public charging infrastructure but a slower electric vehicle uptake, additional local actions (e.g., building codes, zoning, regulations, tax exemptions) to support the charging infrastructure—home, workplace, curbside—are key, especially as the market broadens to those without dedicated home charging.

Most national governments have provided extensive funding for the extension of the public charging infrastructure network. The German government provides funding of €300 million over a 3-year period, and the British government supports in cooperation with the private sector the rollout of public charging infrastructure with an investment of €470 million between 2019 and 2020. As most charging is done at home or at workplaces, some national and local governments also provide incentives for charging installations for specific target groups, specifically households (Austria, France/Paris, Sweden, United Kingdom), housing associations (Finland, Oslo), businesses (Netherlands, Spain, Sweden), and taxi operators (Oslo).

In the context of electric vehicle ready building codes to increase charging accessibility, the European Commission's "Energy Performance of Buildings Directive" mandates EU countries to submit a national framework by March 2020 to simplify the deployment of recharging points in buildings by adapting their permitting and approval procedures accordingly (Official Journal of the European Union, 2018). Starting then, electric vehicle-ready building codes are expected to become a more common measure to increase consumer convenience in terms of charging options.

In addition to the above predominantly local policies, overarching regulations drive automaker, battery supplier, and charging industry investments. European-level vehicle CO_2 regulations and the policy-stimulated development in non-European markets, such as China, require companies to move to higher-volume electric production scale, more widespread electric model availability across types and brands, and greater marketing efforts. This, in turn, drives battery costs down and gives more consumers electric vehicle options. In the markets analyzed here, between 17 and 43 different electric models were available in 2018, indicating most companies are at volumes too low to widely offer their electric products across Europe. In addition, the adoption of national electric vehicle-ready building codes as mandated by the European Commission accelerates the expansion of the charging infrastructure network, increasing the accessibility to a broader population of prospective electric vehicle consumers.

Despite the promising developments, European markets, with the exception of Norway, remain far from their ambitious goals to move to all zero-emission vehicles. Goals for cities and nations to move to all-electric mobility are typically for the 2030–2050 time frame (Slowik, Hall, Lutsey, Nicholas, & Wappelhorst, 2019). The top European electric markets outside Norway are typically more like 5% to 13% electric share. Although not the focus of this study, stronger policy tools with long-term certainty, like more stringent CO_2 standards for 2030 and beyond are the most direct way to achieve such goals in European markets.

Until such stronger vehicle requirements are in place, European cities are primed to lead the way toward electric mobility. Beyond national government activities such as incentives and subsidy schemes, cities play a key role in implementing policy and

overcoming persistent consumer awareness and convenience barriers, including sustained local-level financial and nonfinancial incentives, campaigns, and charging infrastructure planning. The actions identified herein demonstrate how some cities in Europe are developing, adopting, and sharpening their policy tools to lead the electric mobility transition.

REFERENCES

ACEA (European Automobile Manufacturers Association). (2018). *ACEA Tax Guide*. Retrieved from https://www.acea.be/uploads/news_documents/ACEA_Tax_Guide_2018.pdf

ADAC. (2019). Privilegien für Elektrofahrzeuge in Städten [Privileges for electric vehicles in cities]. Retrieved from https://www.adac.de/rund-ums-fahrzeug/e-mobilitaet/info/vorteile-elektroauto-stadt/

Amundsen, A. H., & Sundvor, I. (2018). *Low emission zones in Europe. Requirements, enforcement and air quality*. Retrieved from https://www.toi.no/getfile.php?mmfileid=49204

Avere-France. (2017). Comment bénéficier du crédit d'impôt transition énergétique de 300 euros pour bornes de recharge? [How to benefit from the energy transition tax credit of 300 euros for charging stations?]. Retrieved from http://www.avere-france.org/Site/Article/?article_id=6091

Avere-France. (2019). Quels sont les montants de l'aide? [What are the amounts of the aid?] Retrieved from http://advenir.mobi/montant/

Berg, L. M. N. (2018). How did Oslo become the electric vehicle capital of the world? Retrieved from Thomson Reuters Foundation website, http://news.trust.org/item/20180307114110-a0cqx/

Berliner Agentur für Elektromobilität eMO. (2014). Berlin-Brandenburg elektrisiert. Aktionsprogramm Elektromobilität 2020 [Berlin-Brandenburg electrifies. Action program for electric mobility 2020]. Retrieved from https://www.berlin.de/sen/wirtschaft/wirtschaft/innovation-und-qualifikation/cluster/ikt-medien-und-kreativwirtschaft/aktionsprogramm_elekromobilitat_2020.pdf

Berliner Agentur für Elektromobilität eMO. (2019). Wegweiser [Signpost]. Retrieved from https://www.emo-berlin.de/de/wegweiser/ueberblick/

Brussels Environment. (n.d.). Sortie du thermique (véhicules diesel et essence) [Thermal output (diesel and petrol vehicles)]. Retrieved from https://environnement.brussels/thematiques/mobilite/sortie-du-thermique-vehicules-diesel-et-essence

Brussels Environment. (2018). Gestion du parc automobile des autorités dans le cadre du PDE [Management of the fleet of authorities under the PDE]. Retrieved from https://environnement.brussels/thematiques/mobilite/les-plans-de-deplacements/plan-de-deplacements-entreprise/plan-dactions-vos-9

Bürgerschaft der freien und Hansestadt Hamburg. (2015). Mitteilung des Senats an die Bürgerschaft [Notification from the Senate to the citizens]. Retrieved from https://www.hamburg.de/contentblob/4658414/b246fbfbbf1149184431706972709508/data/d-21-2521-hamburger-klimaplan.pdf

City of Amsterdam. (n.d.). Charging and parking electric vehicles. Retrieved from https://www.amsterdam.nl/en/parking/electric-charging/

City of Amsterdam. (2015). Policy: Sustainability and energy. Retrieved from https://www.amsterdam.nl/en/policy/sustainability/

City of Brussels. (n.d.). Electric charging points. Retrieved from https://www.brussels.be/electric-charging-points

City of Brussels. (2018). First public charging point for electric cars. Retrieved from https://www.brussels.be/first-public-charging-point-electric-cars

City of Helsinki. (2017). Lisää sähköautojen latauspisteitä Helsingin kantakaupunkiin [Add recharging points for electric cars to Helsinki city center]. Retrieved from https://www.hel.fi/uutiset/fi/helsinki/lisaa-sahkoautojen-latauspisteita

City of Helsinki. (2018a). Vähäpäästöisten autojen pysäköintimaksujen alennus [Reduced parking fees for low emission cars]. Retrieved from https://www.hel.fi/helsinki/fi/kartat-ja-liikenne/pysakointi/vahapaastoisten_alennus

City of Helsinki. (2018b). Helsinki to kick off electric car marathon race. Retrieved from https://www.hel.fi/uutiset/en/helsinki/helsinki-to-kick-off-electric-car-marathon-race

City of Oslo. (2016). Klima- og energistrategi for Oslo [Climate and energy strategy for Oslo]. Retrieved from https://www.oslo.kommune.no/getfile.php/1356550-1480689984/Tjenester%20og%20tilbud/Politikk%20og%20administrasjon/Etater%2C%20foretak%20og%20ombud/Klimaetaten/Dokumenter%20og%20rapporter/Klima-%20og%20energistrategi%20for%20Oslo%20NO.pdf

City of Oslo. (2017). *Climate budget 2018*. Retrieved from https://www.klimaoslo.no/wp-content/uploads/sites/88/2018/02/Climate-Budget-English.pdf

City of Paris. (2018). *Paris climate action plan*. Retrieved from https://api-site-cdn.paris.fr/images/101081

City of Stockholm. (2019). Laddgator i Stockholm [Charging streets in Stockholm]. Retrieved from https://www.stockholm.se/Fristaende-webbplatser/Fackforvaltningssajter/Miljoforvaltningen/Miljobilar/Bilar--branslen/Miljobranslen/Laddgator-i-Stockholm/

City of Vienna. (2019). Elektrotankstellen—Anbieter in Österreich [Electric filling stations — provider in Austria]. Retrieved from https://www.stadt-wien.at/lifestyle/alternative-mobilitaet/elektrotankstellen-anbieter-in-oesterreich.html

City of Westminster. (n.d.). Electric vehicles. Retrieved from https://www.westminster.gov.uk/electric-vehicles

Congreso de los Disputados (2019). Proposición de Ley sobre Cambio Climático y Transición Energética [Proposed Law on Climate Change and Energy Transition]. Retrieved from http://www.congreso.es/public_oficiales/L13/CONG/BOCG/B/BOCG-13-B-48-1.PDF

Den Haag. (n.d.). Laadpaal voor elektrische auto aanvragen [Provide location for electric charging]. Retrieved from https://www.denhaag.nl/nl/meldingen/meldingen-verkeer/locatie-voor-elektrisch-opladen-doorgeven.htm#

Deutscher Bundestag. (2018). Geplante Steuervergünstigung für Privatnutzung von E-Autos strittig bewertet [Planned tax deduction for private use of electric cars disputed]. Retrieved from https://www.bundestag.de/dokumente/textarchiv/2018/kw42-pa-finanzen-onlinehandel-572528

Die Bundesregierung. (2009). Nationaler Entwicklungsplan Elektromobilität der Bundesregierung [National development plan for electromobility of the German government]. Retrieved from https://www.erneuerbar-mobil.de/sites/default/files/2016-08/nep_09_bmu_bf.pdf

Die Bundesregierung. (2019). Eckpunkte für das Klimaschutzprogramm 2030 [Key points for the Climate Protection Program 2030]. Retrieved from https://www.bundesregierung.de/resource/blob/997532/1673502/768b67ba939c098c994b71c0b7d6e636/2019-09-20-klimaschutzprogramm-data.pdf?download=1

Dirección General de Tráfico. (2019, June 27). Matriculaciones definitivas – 2018 – Anuario aux [Final registrations – 2018 – auxilary yearbook]. Retrieved from http://www.dgt.es/Galerias/seguridad-vial/estadisticas-e-indicadores/matriculaciones-definitivas/por-provincia-y-tipo/doc/aux_matriculaciones_2018_anuario.xlsx

Ecomotion. (2018). VEM (Vehículos Eléctricos Madrid) 2018 [VEM (Electric Vehicles Madrid) 2018]. Retrieved from http://www.ecomotion.es/evento/vem-vehiculos-electricos-madrid-2018-H8x1t

e-mobility-nsr. (2017). EMIC in Amsterdam. Retrieved from http://e-mobility-nsr.eu/centres/amsterdam/

Enedis. (2018). La mobilité électrique, partout et pour tous [Electric mobility, everywhere and for everyone]. Retrieved from https://www.enedis.fr/sites/default/files/Mobilite_Electrique_LD.pdf

Electrive.com. (2019, March 3). Oslo: Charging electric cars no longer free of charge. Retrieved from https://www.electrive.com/2019/03/03/oslo-charging-electric-cars-no-longer-free-of-charge/

Electrive.com. (2020, February 4). UK to bring ICE ban forward by 5 years to 2035. Retrieved from https://www.electrive.com/2020/02/04/uk-aims-to-bring-ice-ban-forward-by-5-years/

Erle, C. (2016). The Hamburg master plan — A charging infrastructure for electric cars. Retrieved from the Management Circle website, https://www.management-circle.de/blog/der-hamburger-masterplan-eine-ladeinfrastruktur-fuer-elektroautos/

European Alternative Fuels Observatory (2019). European Union. Retrieved from https://www.eafo.eu/countries/european-union/23640/summary

Eurostat. (n.d.). Metropolitan Regions. Retrieved from https://ec.europa.eu/eurostat/web/metropolitan-regions/background

EV-Volumes. (2019). EV Data Center, 2019. http://www.ev-volumes.com/datacenter/

Federal Ministry of Economy and Energy. (2019). Electromobility in Germany. Retrieved from https://www.bmwi.de/Redaktion/DE/Dossier/elektromobilitaet.html

Federal Ministry of Transport and Digital Infrastructure. (2019). Förderrichtlinie ladeinfrastruktur für elektrofahrzeuge [Promotional guideline for charging infrastructure for electric vehicles]. Retrieved from https://www.bmvi.de/SharedDocs/DE/Artikel/G/foerderrichtlinie-ladeinfrastruktur-elektrofahrzeuge.html

Federal Office of Energy. (n.d.). Lancierung der Plattform Ladenetz Schweiz [Launch of the Swiss charging network platform]. Retrieved from https://www.energieschweiz.ch/page/de-ch/lancierung-der-plattform-ladenetz-schweiz

FleetNews. (2019). No company car tax on electric vehicles, says Government. Retrieved from https://www.fleetnews.co.uk/news/fleet-industry-news/2019/07/09/no-company-car-tax-on-electric-vehicles-says-government

Fleet World. (2019). London lamp posts to plug EV charging gaps. Retrieved from https://fleetworld.co.uk/london-lamp-posts-to-plug-ev-charging-gaps/

HafenCity Universität Hamburg. (2018). Elektromobilität im Rahmen der Stadtentwicklung in Hamburg und Shenzhen [Electromobility in the context of urban development in Hamburg .and Shenzhen]. Retrieved from http://edoc.sub.uni-hamburg.de/hcu/volltexte/2018/402/pdf/SINGER_Dokumentation_Elektromobilitaet_und_Stadtentwicklung_HCU_2018.pdf

Hall, D., Cui, H.; Lutsey, N. (2019). Electric vehicle capitals: Showing the path to a mainstream market. Retrieved from the International Council on Clean Transportation, https://theicct.org/publications/ev-capitals-of-the-world-2019

Hammersmith & Fulham. (n.d.). Green vehicle permits. Free permits for fully electric vehicles. Retrieved from https://www.lbhf.gov.uk/parking/parking-permits/green-vehicle-permits

IHS Markit. (2019). New vehicle registration data. Retrieved from https://ihsmarkit.com/

Institute for Diversification and Energy Saving. (2018). Plan MOVALT infraestructura (MOVALT infrastructure plan. Retrieved from https://www.idae.es/ayudas-y-financiacion/para-movilidad-y-vehiculos/plan-movalt-infraestructura

Investitionsbank Berlin. (2018). Wirtschaftsnahe Elektromobilität [Business-related electromobility] (WELMO). Retrieved from https://www.ibb.de/de/foerderprogramme/wirtschaftsnahe-elektromobilitaet.html

KBA (Kraftfahrtbundesamt [Federal Motor Transport Authority]). (2019). Jahresbilanz der Neuzulassungen 2018 [Annual balance of new registrations 2018]. Retrieved from: https://www.kba.de/DE/Statistik/Fahrzeuge/Neuzulassungen/n_jahresbilanz.html?nn=644522

Klima- und Energiefonds. (2018). *Leitfaden e-mobilität für private [Guideline e-mobility for private households].* Retrieved from https://www.klimafonds.gv.at/wp-content/uploads/sites/6/LeitfadenEmobilitaetPrivate.pdf

Kommunalkredit Public Consulting GmbH. (2019). Förderungsaktion E-Ladeinfrastruktur [Promotion e-charging infrastructure]. Retrieved from https://www.umweltfoerderung.at/fileadmin/user_upload/media/umweltfoerderung/Dokumente_Betriebe/Fahrzeuge__Mobilitaet__Verkehr/UFI_Pauschalen_Infoblatt_E-INFRA_PAU.pdf

Korkia. (2019). Yritysten investointituki sähköautojen julkisille latauspisteille [Enterprise investment aid for public recharging points for electric vehicles]. Retrieved from http://www.lataustuki.fi/

Madrid City Council. (2017). El Ayuntamiento destina 1,5 millones para subvenciones a 'ecotaxis' [The City Council allocates 1.5 million for grants to 'ecotaxis']. Retrieved from https://www.madrid.es/portales/munimadrid/es/Inicio/El-Ayuntamiento/Medios-de-comunicacion/Todas-las-noticias/El-Ayuntamiento-destina-1-5-millones-para-subvenciones-a-ecotaxis?vgnextfmt=default&vgnextoid=2fa81185c6c8c510VgnVCM1000001d4a900aRCRD&vgnextchannel=e40362215c483510VgnVCM2000001f4a900aRCRD

Madrid City Council. (2018a). Las 30 medidas [The 30 measures]. Retrieved from https://www.madrid.es/portales/munimadrid/es/Inicio/Medio-ambiente/Las-30-medidas?vgnextfmt=default&vgnextoid=0590b83903a50610VgnVCM1000001d4a900aRCRD&vgnextchannel=3edd31d3b28fe410VgnVCM1000000b205a0aRCRD

Madrid City Council. (2018b). Madrid Central. Información General [Central Madrid general information]. Retrieved from https://www.madrid.es/portales/munimadrid/es/Inicio/Movilidad-y-transportes/Madrid-Central-Zona-de-Bajas-Emisiones/Informacion-general/Madrid-Central-Informacion-General/?vgnextfmt=default&vgnextoid=a67cda4581f64610VgnVCM2000001f4a900aRCRD&vgnextchannel=088e96d2742f6610VgnVCM1000001d4a900aRCRD

Magistrat der Stadt Wien. (2016). E-mobilitätsstrategie [E-mobility strategy]. Retrieved from https://www.wien.gv.at/stadtentwicklung/studien/pdf/b008435.pdf

Mairie de Paris. (2018). *Plan Climat de Paris* [*Climate Plan of Paris]*. Retrieved from https://www.apc-paris.com/system/files/file_fields/2018/04/20/nouveauplanclimat.pdf

Mayor of London. (2016). *Parking Standards*. Retrieved from https://www.london.gov.uk/sites/default/files/parking_standards_malp_for_publication_7_april_2016.pdf

Mayor of London. (2018). *Mayor's Transport Strategy*. Retrieved from https://www.london.gov.uk/sites/default/files/mayors-transport-strategy-2018.pdf

Mayor of London & Transport for London. (2018). *Changes to the congestion charge. Report to the mayor on the consultation*. Retrieved from https://www.london.gov.uk/sites/default/files/appendix_2_-_report_to_mayor_with_apx.pdf

Ministère de la Transition Écologique et Solidaire. (2019, May 24). Données sur les immatriculations des véhicules [Vehicle registration data]. Retrieved from https://www.statistiques.developpement-durable.gouv.fr/donnees-sur-les-immatriculations-des-vehicules?rubrique=58&dossier=1347

Ministries' security and service organization. (2017). *Bedre vekst, lavere utslipp*

– *Regjeringens strategi for grønn konkurransekraft [Better growth, lower emissions*

– *The government's strategy for green competitiveness].* Retrieved from https://www.regjeringen.no/contentassets/4a98ed15ec264d0e938863448ebf7ba8/t-1562b.pdf

Ministry of Ecological and Solidarity Transition. (2018). Bonus-malus écologique, prime à la conversion et bonus vélo [Eco-friendly bonus-malus, conversion bonus and bike bonus]. Retrieved from https://www.ecologique-solidaire.gouv.fr/bonus-malus-ecologique-prime-conversion-et-bonus-velo#e2

Ministry of Economic Affairs. (2017). Vision on the charging infrastructure for electric transport. Retrieved from https://www.rvo.nl/sites/default/files/2017/05/Vision%20on%20the%20charging%20infrastructure%20for%20electric%20transport.pdf

Ministry of Industry, Energy and Tourism. (2014). Real Decreto 1053/2014, de 12 de diciembre, por el que se aprueba una nueva Instrucción Técnica Complementaria (ITC) BT 52 "Instalaciones con fines especiales. Infraestructura para la recarga de vehículos eléctricos", del Reglamento electrotécnico para baja tensión, aprobado por Real Decreto 842/2002, de 2 de agosto, y se modifican otras instrucciones técnicas complementarias del mismo. [Royal Decree 1053/2014, of December 12, approving a new Complementary Technical Instruction (ITC) BT 52 "Special purpose installations. Infrastructure for charging electric vehicles," of the Low Voltage Electrotechnical Regulation, approved by Royal Decree 842/2002, of August 2, and other complementary technical instructions are modified]. Retrieved from https://www.boe.es/diario_boe/txt.php?id=BOE-A-2014-13681

Ministry of Transport. (2017). Nasjonal transportplan 2018–2029. En grønnere transporthverdag [National Transportation Plan 2018–2029. A greener transport day]. Retrieved from https://www.regjeringen.no/no/aktuelt/en-gronnere-transporthverdag/id2548633/

Mock, P. (2018). *European vehicle market statistics. Pocketbook 2018/19*. Retrieved from https://theicct.org/sites/default/files/publications/ICCT_Pocketbook_2018_Final_20190408.pdf

Municipality of Amsterdam. (n.d.b). Amsterdam elektrisch [Amsterdam electric]. Retrieved from https://www.amsterdam.nl/parkeren-verkeer/amsterdam-elektrisch/

Municipality of Amsterdam (n.d.c). Elektrische laadpunten [Electric charging points]. Retrieved from https://www.amsterdam.nl/veelgevraagd/?productid=%7BFAF05E2C-E0B3-472C-8205-48F58315FDD1%7D#case_%7B68FA7E06-9364-4293-A690-52E320E0EC21%7D

Municipality of Amsterdam (n.d.). Routekaart Amsterdam Klimaatneutraal 2050 [Amsterdam Climate Neutral Route Map 2050]. Retrieved from https://www.amsterdam.nl/bestuur-organisatie/volg-beleid/ambities/gezonde-duurzame/klimaatneutraal/#h4f3652c3-2da8-41e2-b06c-f8aba6dc84d4

Municipality of Amsterdam. (n.d.d) Volg het beleid: schone lucht [Follow the policy: clean air]. Retrieved from https://www.amsterdam.nl/bestuur-organisatie/volg-beleid/duurzaamheid-energie/schone-lucht/

Municipality of Oslo. (n.d.a). Lade og parkere elbil [Charge and park electric car]. Retrieved from https://www.oslo.kommune.no/gate-transport-og-parkering/parkering/lade-og-parkere-elbil/#gref

Municipality of Oslo. (n.d.b). Ladetilskudd til borettslag og sameier [Grants for charging infrastructure in housing cooperatives and co-owners]. Retrieved from https://www.oslo.kommune.no/politikk-og-administrasjon/tilskudd-legater-og-stipend/tilskudd-til-ladeinfrastruktur-i-borettslag-og-sameier/#gref

Municipality of Rotterdam. (n.d.). Subsidie elektrische bestelauto voor zakelijk gebruik [Subsidy for electric delivery van for business use]. Retrieved from https://www.rotterdam.nl/loket/subsidie-bestelauto-voor-zakelijk-gebruik/

Netherlands Enterprise Agency. (n.d.). Rijksbijdrage laadinfrastructuur voor elektrische auto's [Government grant charging infrastructure for electric cars]. Retrieved from https://www.rvo.nl/subsidies-regelingen/rijksbijdrage-laadinfrastructuur-voor-elektrische-autos

NGIN Mobility. (2019). Aus Laternen werden Ladestationen: Berlin eifert London nach [Lampposts become charging stations: Berlin emulates London]. Retrieved from https://ngin-mobility.com/artikel/ubitricity-berlin-ladestation-elektromobilitaet/

Nicholas, M., & Hall, D. (2018). *Lessons learned on early electric vehicle fast-charging deployments.* Retrieved from the International Council on Clean Transportation, https://www.theicct.org/publications/fast-charging-lessons-learned

Norsk elbilforening. (n.d.). Norwegian EV policy. Norway is leading the way for a transition to zero emission in transport. Retrieved from https://elbil.no/english/norwegian-ev-policy/

Norwegian Tax Administration. (n.d.). Road traffic insurance tax. Retrieved from https://www.skatteetaten.no/en/business-and-organisation/vat-and-duties/excise-duties/about-the-excise-duties/road-traffic-insurance/

NWB Verlag. (2019). Jahressteuergesetz 2019 [Annual Tax Act 2019]. Retrieved from https://datenbank.nwb.de/Dokument/Anzeigen/779247/

Office for Low Emission Vehicles. (2018a). *Electric vehicle homecharge scheme guidance for customers: version 2.2*. Retrieved from https://webarchive.nationalarchives.gov.uk/20181001231206/https://www.gov.uk/government/publications/electric-vehicle-homecharge-scheme-guidance-for-customers-version-22

Office for Low Emission Vehicles. (2018b). *Workplace charging scheme guidance for applicants, installers and manufacturers*. Retrieved from https://www.gov.uk/government/publications/workplace-charging-scheme-guidance-for-applicants-installers-and-manufacturers

Office for Low Emission Vehicles. (2019). *Grants to provide residential on-street chargepoints for plug-in electric vehicles. Guidance for local authorities*. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/792884/onstreet-chargepoint-residential-scheme-guidance.pdf

Official Journal of the European Union. (2018). Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L0844&from=EN

Open Charge Point Belgium. (n.d.). Openchargepoint.be — Kwaliteitslabel voor publieke laadpunten — Gedragscode (code of conduct) [Openchargepoint.be. Quality label for public charging points. Code of conduct.] Retrieved from http://www.openchargepoint.be/wat-is-ocp.html

Parclick (n.d.). Car parks near APR Zones in Madrid. Retrieved from https://parclick.com/parking/park-in-madrids-apr-zones

Paris. (2019a). Les aides financières pour inciter à des mobilités propres [Financial incentives to encourage clean mobility]. Retrieved from https://www.paris.fr/pages/lutte-contre-la-pollution-les-aides-a-la-mobilite-5373/

Paris. (2019b). De nombreuses offres existent pour les véhicules électriques et en autopartage [Many offers exist for electric vehicles and carsharing]. Retrieved from https://www.paris.fr/pages/de-nombreuses-offres-existent-pour-les-vehicules-electriques-et-en-autopartage-5930/

Paris. (2019c). Véhicules électriques et bornes de recharge [Electric vehicles and charging stations]. Retrieved from https://www.paris.fr/pages/vehicules-electriques-2776

PitPoint. (2019). Charge. Brussels. Retrieved from https://www.charge.brussels/

RACC (Reial Automòbil Club de Catalunya). (2019). ¿Cómo funciona un carril VAO? ¿Quién puede usarlo? [How does a VAO lane work? Who can use it?] Retrieved from http://blog.racc.es/coche/carril-vao-vehiculos-alta-ocupacion/

Regeringen. (2018). *Sammen om en grønnere fremtid. Klima- og luftudspil [Together for a greener future – Climate and air play].* Retrieved from https://efkm.dk/media/12350/klimaministeriet_klimaogluftudspil_digital.pdf

Région de Bruxelles-Capitale. (2019). *Plan énergie climat 2030 [Energie and climate plan 2030].* Retrieved from https://environnement.brussels/sites/default/files/user_files/pnec_rbc_fr.pdf

République Française. (2016). Décret n° 2016-968 du 13 juillet 2016 relatif aux installations dédiées à la recharge des véhicules électriques ou hybrides rechargeables et aux infrastructures permettant le stationnement des vélos lors de la construction de bâtiments neufs [Decree No. 2016-968 of July 13th, 2016 relative to the installations dedicated to the recharging of electric vehicles or rechargeable hybrids and infrastructures allowing the parking of the bicycles during the construction of new buildings]. Retrieved from https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000032894192&categorieLien=id

République Française. (2018). Arrêté du 8 février 2018 portant reconduction des programmes « FEEBAT » et « Advenir » dans le cadre du dispositif des certificats d'économies d'énergie [Order of February 8, 2018 renewing the "FEEBAT" and "Advenir" programs as part of the energy savings certificate system]. Retrieved from https://www.legifrance.gouv.fr/affichTexte.do;jsessionid=C022B5511598AEF1CF9D2E76092093FB.tplgfr22s_3?cidTexte=JORFTEXT000036671835&dateTexte=29990101

République Française (2019). LOI n° 2019-1428 du 24 décembre 2019 d'orientation des mobilités [Law Number 2019-1428 of 24 December 2019 on Mobility Orientation]. Retrieved from https://www.legifrance.gouv.fr/affichTexte.do?categorieLien=id&cidTexte=JORFTEXT000039666574&dateTexte=

Rijksoverheid. (n.d.). 3.2 Mobiliteit [3.2 Mobility]. Retrieved from https://www.rijksoverheid.nl/regering/regeerakkoord-vertrouwen-in-de-toekomst/3.-nederland-wordt-duurzaam/3.2-mobiliteit

SCB—Statistics Sweden. (2019). Statistical news. Retrieved from: https://www.scb.se/en/finding-statistics/statistical-news/?selectedProduct=TK1001

Senate Department for Urban Development and Housing. (2015). Berliner Modell wird Realität: erste Ladesäule für Elektrofahrzeuge mit neuem Konzept geht ans Netz [Berlin model becomes reality: first charging station for electric vehicles with a new concept goes online.] Retrieved from https://www.stadtentwicklung.berlin.de/aktuell/pressebox/archiv_volltext.shtml?arch_1504/nachricht5567.html

Slowik, P., & Lutsey, N. (2018). *The continued transition to electric vehicles in U.S. cities*. Retrieved from the International Council on Clean Transportation, https://www.theicct.org/publications/continued-EV-transition-us-cities-2018

Slowik, P., & Lutsey, N. (2019). *The surge of electric vehicles in*

United States cities. Retrieved from the International Council on Clean Transportation, https://theicct.org/sites/default/files/publications/ICCT_EV_surge_US_cities_20190610.pdf

Slowik, P., Hall, D., Lutsey, D., Nicholas, M., & Wappelhorst, S. (2019). *Funding the transition to all zero-emission vehicles*. Retrieved from the International Council on Clean Transportation, https://theicct.org/publications/funding-ZEV-transition

SMMT (The Society of Motor Manufacturers and Traders). (2019). SMMT vehicle data – car registrations. Retrieved from https://www.smmt.co.uk/vehicle-data/car-registrations/

Sweden's Parliament. (2015). Förordning (2015:517) om stöd till lokala klimatinvesteringar [Regulation (2015: 517) on support for local climate investments]. Retrieved from https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/forordning-2015517-om-stod-till-lokala_sfs-2015-517

Swedish Ministry of Environment and Energy. (2017). Förordning (2017:1318) om bidrag till privatpersoner för installation av laddningspunkt till elfordon [Ordinance (2017: 1318) on grants to private persons for the installation of charging points for electric vehicles]. Retrieved from https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/forordning-20171318-om-bidrag-till_sfs-2017-1318

Swedish Transport Agency. (n.d.). Congestion taxes in Stockholm and Gothenburg. Retrieved from https://www.transportstyrelsen.se/en/road/Congestion-taxes-in-Stockholm-and-Goteborg/

Terberg Leasing. (2018). In Rotterdam krijgen elektrische voertuigen nieuwe privileges [Electric vehicles are given new privileges in Rotterdam]. Retrieved from https://www.terbergleasing.nl/over-ons/actueel/nieuws/in-rotterdam-krijgen-elektrische-voertuigen-nieuwe-privileges/

The Government of Denmark. (2018). Sammen om en grønnere fremtid [Together for a greener future]. Retrieved from https://www.regeringen.dk/nyheder/miljoe-og-klimaudspil/

The Royal Borough of Kensington and Chelsea. (2019). Electric vehicles. Retrieved from https://www.rbkc.gov.uk/parking-transport-and-streets/visitors/visitor-parking/electric-vehicles

Transport Styrelsen. (n.d.). Bonus – till bilar med låga utsläpp [Bonus – for cars with low emissions]. Retrieved from https://www.transportstyrelsen.se/sv/vagtrafik/Fordon/bonus-malus/bonus/

Vienna Online. (2018). An öffentlichen E-Ladestationen in Wien noch bis 1. Oktober gratis laden [Charge for free at public e-charging stations in Vienna until October 1]. Retrieved from https://www.vienna.at/an-oeffentliche-e-ladestationen-in-wien-noch-bis-1-oktober-gratis-laden/5934650

Virta. (2018). Kolme tukea sähköauton latauspisteiden toteuttamiseen [Three support for implementing electric car charging points]. Retrieved from https://www.virta.global/fi/blogi/tuet-sahkoauton-latauspisteiden-toteuttamiseen

Volkswagen AG. (2019). Brands and models: Volkswagen. Retrieved from https://www.volkswagenag.com/en/brands-and-models/volkswagen.html

Wappelhorst, S., Mock, P., & Yang, Z. (2018). *Using vehicle taxation policy to lower transport emissions: An overview for passenger cars in Europe.* Retrieved from the International Council on Clean Transportation, https://www.theicct.org/sites/default/files/publications/EU_vehicle_taxation_Report_20181214_0.pdf

Wappelhorst, S., & Tietge, U. (2018). *Sweden's new bonus-malus scheme: From rocky roads to rounded fells?* Retrieved from the International Council on Clean Transportation, https://theicct.org/blog/staff/swedens-feebate-system-20181008

Wien Energie. (n.d.a). Wien Energie setzt sich für die Mobilitätswende ein [Wien Energie is committed to the mobility transition]. Retrieved from https://www.tanke-wienenergie.at/1000-ladestellen/

Wien Energie. (n.d.b). Charging solutions for electric cars. Retrieved from https://www.wienenergie.at/eportal3/ep/channelView.do/channelId/-2000103

Wien Energie. (2017). Öffentliche Ladeinfrastruktur in Wien – Ausbau bis 2020 [Public charging infrastructure in Vienna - expansion until 2020]. Retrieved from https://www.oegut.at/downloads/pdf/bautraegerfruehstueck_3_gredler-handout_2017_12_06.pdf?m=1514385479

Wien Energie. (2019). 1000 Ladestellen für Wien [1,000 charging points for Vienna]. Retrieved from https://1000.wienenergie.at/eportal3/

Wiener Landtag. (2018). Gesetz, mit dem die Bauordnung für Wien, das Wiener Kleingartengesetz 1996, das Wiener Garagengesetz 2008, das Wasserversorgungsgesetz und das Wiener Wohnbauförderungs- und Wohnhaussanierungsgesetz – WWFSG 1989 geändert werden (Bauordnungsnovelle 2018) [Act amending the Building Regulations for Vienna, the Vienna Allotment Garden Act 1996, the Vienna Garages Act 2008, the Water Supply Act and the Vienna Housing Promotion and Housing Rehabilitation Act - WWFSG 1989 (Building Code Amendment 2018]. Retrieved from https://www.ris.bka.gv.at/Dokumente/LgblAuth/LGBLA_WI_20181221_69/LGBLA_WI_20181221_69.pdfsig

Wiener Stadtwerke. (2019). eTaxi Wien [eTaxi Vienna]. Retrieved from https://www.wienerstadtwerke.at/eportal3/ep/programView.do/pageTypeId/71282/programId/4401692/channelId/-51285

WSP Sverige AB. (2018). Eltransporter Stockholm 2030 [Electric Transport Stockholm 2030]. Retrieved from http://www.elbilsverige.se/wp-content/uploads/2018/07/d6c3252d-3d30-4c8b-9524-a13147df7721.pdf

APPENDIX

Table A1. Representative electric vehicle promotion actions in 2018.

Promotion action	Level	Example and Link
BEV purchase benefit	National	Paris (France) – Bonus écologique pour un véhicule électrique (voiture, scooter, moto, vélo, ...) [Ecological bonus for an electric vehicle]. https://www.service-public.fr/particuliers/vosdroits/F34014
PHEV purchase benefit	National	Berlin, Hamburg (Germany) – Elektromobilität (Umweltbonus) [Electric mobility (bonus payment)]. https://www.bafa.de/DE/Energie/Energieeffizienz/Elektromobilitaet/elektromobilitaet_node.html
BEV registration tax benefit	National	Oslo (Norway) – Norwegian EV policy. https://elbil.no/english/norwegian-ev-policy/
PHEV registration tax benefit	National	Copenhagen (Denmark) – Betaling af og satser for registreringsafgift [Payment and rates for registration fee]. https://skat.dk/skat.aspx?oid=2234529
BEV ownership tax benefit	National	Rotterdam-The Hague (Netherlands) – Hoeveel motorrijtuigenbelasting moet ik betalen? [How much motor vehicle tax do I have to pay?] https://www.belastingdienst.nl/wps/wcm/connect/nl/auto-en-vervoer/content/hulpmiddel-motorrijtuigenbelasting-berekenen
PHEV ownership tax benefit	National	Stockholm (Sweden) – Bonus – for low-emission vehicles. https://transportstyrelsen.se/en/road/Vehicles/bonus-malus/bonus/
EV company car benefit for employees	National	Amsterdam, Rotterdam-The Hague (The Netherlands) – Company lease vehicles. https://business.gov.nl/regulation/company-car/
EV company car benefit for employers	National	Brussels (Belgium) – Les voitures de société deviendront plus chères à partir de 2020 [Company cars will become more expensive from 2020]. https://www.sd.be/ellawebsite/fr/legalnews/8e57d466-8220-4355-a74a-9ab505859799
EV parking benefit	Local	Madrid (Spain) – Madrid Central. Información General [Central Madrid General information]. https://www.madrid.es/portales/munimadrid/es/Inicio/Movilidad-y-transportes/Madrid-Central-Zona-de-Bajas-Emisiones/Informacion-general/Madrid-Central-Informacion-General/?vgnextfmt=default&vgnextoid=a67cda4581f64610VgnVCM2000001f4a900aRCRD&vgnextchannel=088e96d2742f6610VgnVCM1000-001d4a900aRCRD
EV charging benefit	Local	Amsterdam, Rotterdam-The Hague (Netherlands) – Subsidies en regelingen [Subsidies and schemes]. https://nederlandelektrisch.nl/subsidies-financiering/subsidies-en-regelingen
EV infrastructure use and access benefit	Local	London (United Kingdom) – Congestion charge/ULEZ zone. https://tfl.gov.uk/modes/driving/congestion-charge/congestion-charge-zone
Public charger promotion	National	Berlin, Hamburg (Germany) – Elektromobilität in Deutschland [Electromobility in Germany]. https://www.bmwi.de/Redaktion/DE/Dossier/elektromobilitaet.html
Public charger promotion	Local	Stockholm (Sweden) – Laddgator i Stockholm [Charging streets in Stockholm]. https://www.stockholm.se/Fristaende-webbplatser/Fackforvaltningssajter/Miljoforvaltningen/Miljobilar/Bilar--branslen/Miljobranslen/Laddgator-i-Stockholm/
Private and workplace charger promotion	National	Birmingham, London (United Kingdom) – Grant schemes for electric vehicle charging infrastructure. https://www.gov.uk/government/collections/government-grants-for-low-emission-vehicles
Private and workplace charger promotion	Local	Birmingham, London (United Kingdom) – Grant schemes for electric vehicle charging infrastructure. https://www.gov.uk/government/collections/government-grants-for-low-emission-vehicles
EV curbside and lamppost charging program	Local	Rotterdam-The Hague (Netherlands) – Research on charging light poles in public areas. https://www.elaad.nl/news/research-on-charging-light-poles-in-public-areas/
EV-ready building codes	Local	Madrid (Spain) – Real Decreto 1053/2014, de 12 de diciembre, por el que se aprueba una nueva Instrucción Técnica Complementaria (ITC) BT 52 "Instalaciones con fines especiales. Infraestructura para la recarga de vehículos eléctricos", del Reglamento electrotécnico para baja tensión, aprobado por Real Decreto 842/2002, de 2 de agosto, y se modifican otras instrucciones técnicas complementarias del mismo [Royal Decree 1053/2014, of December 12, approving a new Complementary Technical Instruction (ITC) BT 52 "Special purpose facilities. Infrastructure for charging electric vehicles", of the Low Voltage Electrotechnical Regulation, approved by Royal Decree 842/2002, of August 2, and other complementary technical instructions are modified]. https://www.boe.es/diario_boe/txt.php?id=BOE-A-2014-13681
EV charging interoperability requirements	Local	Amsterdam, Rotterdam-The Hague (Netherlands) - Advancing E-Roaming in Europe: Towards a Single "Language" for the European Charging Infrastructure. https://www.mdpi.com/2032-6653/9/4/50/htm
EV goals	Local	Vienna (Austria) – E-Mobilitätsstrategie [Electromobility strategy]. https://www.wien.gv.at/stadtentwicklung/studien/pdf/b008435.pdf
Public EV procurement	Local	Brussels (Belgium) – Gestion du parc automobile des autorités dans le cadre du PDE [Management of the fleet of authorities under the PDE]. https://environnement.brussels/thematiques/mobilite/les-plans-de-deplacements/plan-de-deplacements-entreprise/plan-dactions-vos-9
EV information and awareness rising	Local	Berlin (Germany) – Wegweiser [Signpost]. https://www.emo-berlin.de/de/wegweiser/ueberblick/