

BRIEFING

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Electric vehicle capitals: Showing the path to a mainstream market

This briefing assesses metropolitan area-level data on electric vehicle registrations and identifies the 25 largest electric vehicle markets, which together represent 42% of new passenger electric vehicle sales globally through 2018. To provide a blueprint for other governments, this briefing analyzes the incentives, charging infrastructure, and city promotion actions in these areas that are spurring electric vehicles into the mainstream.

INTRODUCTION

The electric vehicle market continues to grow worldwide, with the global stock of electric passenger vehicles surpassing 5 million in 2018.¹ Figure 1 illustrates the growth in electric vehicle sales, with the key markets of China, Europe, the United States, and Japan together accounting for over 96% of passenger electric vehicle sales through 2018. These four regions all have regulations that ensure increasing electric vehicle deployment over time. With over 2 million annual sales, the share of new vehicles sold globally that were plug-in electric surpassed 2% in 2018. Global electric vehicle sales growth in 2019 has continued on a similar track, with cumulative sales reaching 6 million in May 2019 and 7 million in November 2019.

¹ EV-Volumes (EV Data Center, 2019), <http://www.ev-volumes.com/datacenter/>.

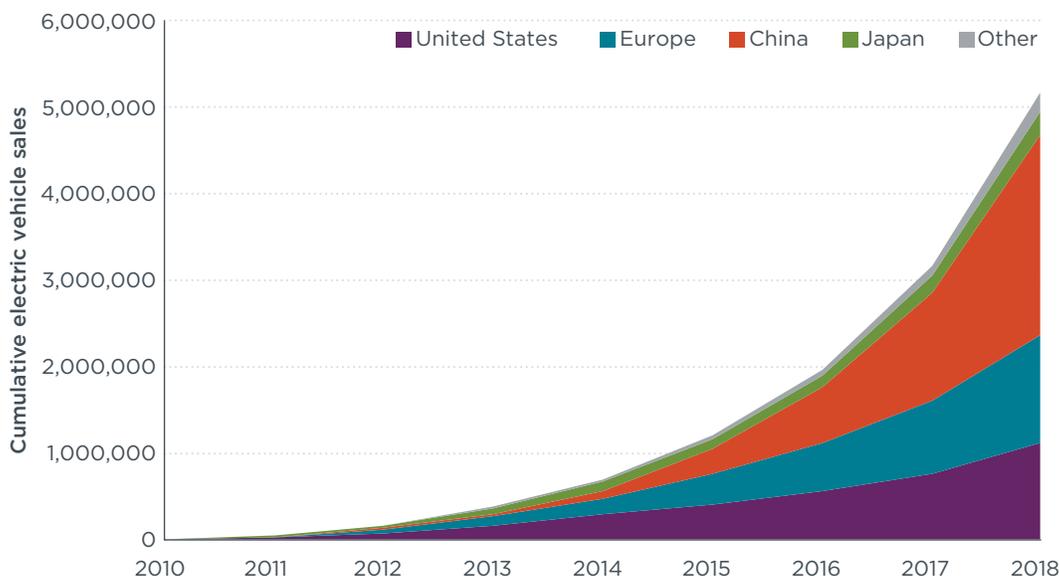


Figure 1. Global electric passenger vehicle sales by market from 2010 to 2018.

This rapid progress has been enabled by sharp declines in battery cost² paired with sustained policy from governments motivated to improve air quality, reduce greenhouse gas emissions, improve energy security, and develop new economic opportunities. While national governments have implemented many guiding policies, local governments have often set even bolder goals and developed unique promotion actions, resulting in significantly higher uptake within specific local markets. In fact, previous research has shown that a small number of metropolitan areas within these regions account for a disproportionate share of electric vehicle shares: through 2017, 25 cities accounted for 44% of the global electric passenger vehicle stock.³

This briefing analyzes the leading role of cities in accelerating the transition to electric vehicles. We identify the 25 cities with the most new passenger electric vehicles through 2018, which we call “electric vehicle capitals”: Shanghai, Beijing, Shenzhen, Hangzhou, Tianjin, Guangzhou, Qingdao, Zhengzhou, Changsha, Weifang, Nanchang, Chongqing, and Wuhan in China; Tokyo, Japan; Oslo and Bergen, Norway; Paris, France; London, United Kingdom; Amsterdam, the Netherlands; Stockholm, Sweden; and Los Angeles, San Francisco, San Jose, New York, and San Diego in the United States. For each of these 25 cities, we assess electric vehicle sales patterns, charging infrastructure deployment, and local promotion actions. Although the markets are named by their major cities, the data throughout include the broader surrounding metropolitan areas.⁴ We analyze markets at the metropolitan area level due to the regional nature of household travel patterns, charging infrastructure, and policy, and to create more consistent definitions across countries. Unless otherwise noted, this

2 Nic Lutsey, Mike Nicholas, *Update on electric vehicle costs in the United States through 2030*, (ICCT: Washington DC, 2019), <https://theicct.org/publications/update-US-2030-electric-vehicle-cost>.

3 Dale Hall, Hongyang Cui, Nic Lutsey, *Electric vehicle capitals: Accelerating the global transition to electric drive*, (ICCT: Washington DC, 2018), <https://theicct.org/publications/ev-capitals-of-the-world-2018>.

4 We use the following definitions: the Metropolitan Statistical Area in the United States, the Metropolitan Region in Europe, the city (市) in China, and the major metropolitan area approximated by prefecture boundaries in Japan.

briefing focuses on light-duty passenger vehicles, which represent the greatest share of fuel consumption and greenhouse gas emissions in the transport sector.

ELECTRIC VEHICLE SALES

Figure 2 shows the cumulative passenger electric vehicle sales through 2018 in the cities around the world with the highest cumulative passenger electric vehicle sales. These sales are broken into battery electric vehicles (BEVs, dark blue) and plug-in hybrid electric vehicles (PHEVs, light blue). It also shows the electric vehicle sales share of new passenger vehicle sales in 2018 for these cities (points, right axis). This figure and local electric vehicle sales estimates throughout are based on the collection and analysis of new registration data.⁵

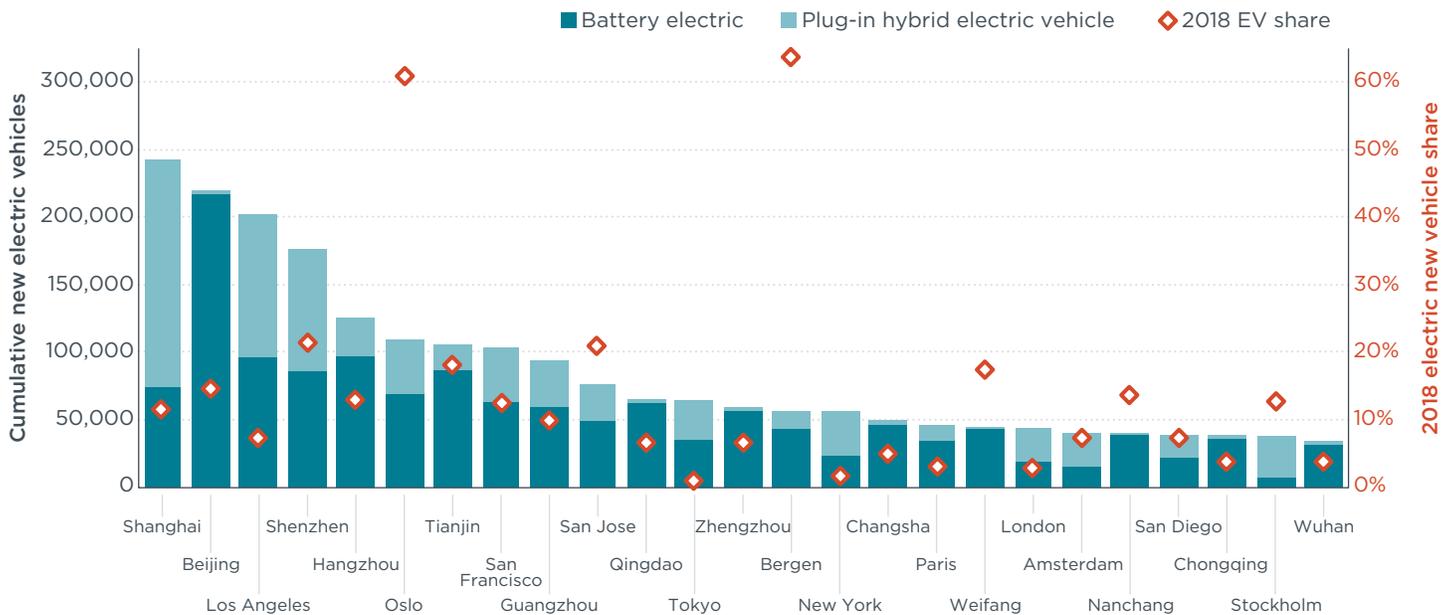


Figure 2. Cumulative electric passenger vehicle through 2018 and 2018 electric vehicle share of new passenger vehicles in the 25 metropolitan areas with the most electric vehicles. (New vehicle registration data are from IHS Markit, Ministère de la Transition Écologique et Solidaire, Norsk Elbilforening, and China Automotive Technology and Research Center)

Shanghai retains its position as the leader in cumulative passenger electric vehicle sales, with over 242,000 through 2018. It is followed by Beijing (220,000) and Los Angeles (202,000). An additional five cities (Shenzhen, Hangzhou, Oslo, Tianjin, and San Francisco) have recorded over 100,000 passenger electric vehicle registrations. Each of the 25 electric vehicle capitals having registered at least 34,000 passenger electric vehicles. When considering BEV sales, Beijing maintains a large lead with about 218,000 cumulative registrations, more than twice the number in second-place Hangzhou (98,000).

⁵ Registration data are from IHS Markit (New vehicle registration data, 2019), <https://ihsmarkit.com/>; Ministère de la Transition Écologique et Solidaire, (Données sur les immatriculations des véhicules [New vehicle registration data], May 24, 2019), <https://www.statistiques.developpement-durable.gouv.fr/donnees-sur-les-immatriculations-des-vehicules?rubrique=58&dossier=1347>; Norsk Elbilforening, EV data for Norway, Personal correspondence, 2019; and Automotive Data Center of China Automotive Technology and Research Center (CATARC), (Market data, 2019), <http://www.catarc.info/scsj/>.

The cities of Oslo and Bergen in Norway continue to experience far greater electric vehicle sales shares than any other market, with 61% and 64% of passenger vehicle sales being electric in 2018, compared to 49% for Norway nationally. Following these were Shenzhen and San Jose (21%), Tianjin (18%), and Weifang (17%). Twelve of these capitals experienced electric vehicle sales shares over 10% in 2018, compared to only five in 2017. BEV sales shares were also highest in Bergen, at 33%, and Oslo, at 24%. Trends in these electric vehicle sales patterns over time are further examined below.

CHARGING INFRASTRUCTURE

Electric vehicle charging infrastructure is key competent in transitioning to electric mobility and has the potential to be one of the most substantial long-term costs in the transition.⁶ Although most electric vehicle charging is done at home, public charging remains an important element to ensure electric vehicles are as convenient as conventional vehicles. In dense urban settings where home charging is typically less available, public charging plays a particularly crucial role.

The deployment of public electric vehicle charging varies widely among the 25 electric vehicle capitals based on the underlying demographic factors (e.g., urban density, housing styles), and associated charging behavior differences.⁷ Figure 2 illustrates the amount of charging available in each city using several metrics: the absolute number of public charge points, the number of public charge points per million population, and the number of electric passenger vehicles per public charge point. Data for Qingdao, Zhengzhou, Changsha, Weifang, Nanchang, and Wuhan were not available. The metropolitan areas are listed from top to bottom by the four main regions, then by decreasing cumulative electric vehicles within each region.

6 Pete Slowik, Dale Hall, Nic Lutsey, Michael Nicholas, Sandra Wappelhorst, *Funding the transition to all zero-emission vehicles*, (ICCT: Washington DC, 2019), <https://theicct.org/publications/funding-ZEV-transition>.

7 Dale Hall, Nic Lutsey, *Emerging best practices for electric vehicle charging infrastructure*, (ICCT: Washington DC, 2017), <https://theicct.org/publications/emerging-best-practices-electric-vehicle-charging-infrastructure>.



Figure 3. Public charging infrastructure in high electric vehicle-uptake metropolitan areas.

Although charging infrastructure networks are complex and differ greatly by region, this high-level observation of the top electric markets globally yields several findings. Firstly, China, and especially the leading cities of Shanghai, Beijing, and Shenzhen, is far outpacing the rest of the world in public charging infrastructure construction. Shenzhen, with its 60,000 public charge points, has more public charge points than the 11 electric vehicle capitals in Europe and the United States combined. Even when adjusting for population, shown in the middle column of Figure 2, Shenzhen has a strong advantage in charging density with over 4,000 charge points per million residents; Oslo, Amsterdam, and Bergen are next highest with over 2,000. When assessing the ratio of electric vehicles per public charge point, shown in the right column, many cities in China, as well as Amsterdam and London, have eight or fewer electric vehicles for each public charge point; in Shenzhen, the ratio is lowest at three to one. On the other hand, the three leading cities in California see electric vehicle-to-public charger ratios closer to 40 to 1, indicating the public charging network may not be keeping pace with electric vehicle market growth, but also reflecting the widespread availability of private home and workplace charging.

Governments at the local, regional, and national level have supported the construction of public and private charging infrastructure through incentives, targets, and building codes. Charging infrastructure incentives often vary with charging speeds and many are targeted toward specific technologies or applications. For example, Guangzhou offered 150 yuan (about \$21) per kilowatt to alternating current (AC) regular chargers, or 550 yuan (\$78) per kilowatt to direct current (DC) fast chargers or AC/DC integrated chargers and wireless charging infrastructure, to developers of public and dedicated (e.g., taxi dedicated) charging stations. Further, Guangzhou provided 2,000 yuan (\$300) per kilowatt to battery swapping projects.⁸ Beijing encouraged the construction of workplace chargers and provided a subsidy of 400 yuan (\$57) per kilowatt to chargers with a power not higher than 7 kilowatts and 500 yuan (\$71) per kilowatt to chargers with a power higher than 7 kilowatts.⁹ The Tokyo Metropolitan Government subsidizes 50%, up to 400,000 yen (\$3,700), of the cost of charging stations for residents or businesses.¹⁰ Paris offers funding for 50% of the hardware and installation costs for charging at multi-unit dwellings or for home charging for taxi drivers.

Building and parking codes are also powerful tools to accelerate the growth of charging infrastructure installation. Local and national governments have increasingly adopted mandates requiring that electric vehicle chargers, or suitable wiring to support such chargers, be included in buildings when built or modified, with the goal of creating universal charging access while minimizing installation costs. For example, Shenzhen mandates that 30% of parking spots in new residential buildings, large-scale public buildings such as hospitals and stadiums, and public parking spaces be equipped with chargers, with the remainder being “EV ready” with appropriate electric wiring and capacity. In addition, 10% of parking spots in existing residential buildings, large-scale public buildings, and public parking spaces are required to be equipped with chargers. For parking spaces in existing government buildings, the percentage requirement is 20%.¹¹ In Guangzhou, all parking spots in new residential buildings are required to be equipped with chargers or include EV-ready wiring. The percentage requirements for new public parking spaces, new curb parking spaces, and parking spots in new highway service areas are 30%, 30% and 50%, respectively.¹² San Francisco requires EV-ready circuitry to supply all parking spots in new residential buildings, and also requires that wiring be added at the time of significant renovations. This goes further than California’s broader EV-ready building codes, which specify that at least 6% of commercial parking spaces be EV-ready.¹³

8 Industry and information technology commission of Guangzhou municipality, “Measures on the management of electric vehicle charging infrastructure subsidy [广州市电动汽车充电基础设施补贴资金管理办法],” (October 2018), <https://www.gz.gov.cn/gzswjk/2.2.11/201810/b8a0c6319fd44c9bb48587021e6b8634.shtml>.

9 City management commission of Beijing municipality, “Guideline on the application of workplace charging infrastructure construction subsidy in Beijing [2019年度北京市单位内部公用充电设施建设补助资金申报指南],” August 2019, http://www.beijing.gov.cn/zhengce/gfxwj/201908/t20190805_102886.html.

10 “Tokyo CO₂ down, Project to promote electric vehicles – external power supply [電気自動車等の普及促進事業（外部給電器）],” accessed September 25, 2019, <https://www.tokyo-co2down.jp/individual/subsidy/ev-feed/index.html>.

11 Development and reform commission of Shenzhen municipality, “Tentative measures on the management of new energy vehicle charging infrastructure in Shenzhen [深圳市新能源汽车充电设施管理暂行办法],” (November 2018), http://www.sz.gov.cn/zfgb/2018/gb1079/201811/t20181127_14738104.htm.

12 Guangdong provincial government, “Views on accelerating the innovation and development of new energy vehicle industry [广东省人民政府关于加快新能源汽车产业创新发展的意见],” (June 2018), http://www.gd.gov.cn/gkmlpt/content/0/146/post_146920.html.

13 International Code Council, 2019 California Green Building Standards Code, Title 24, accessed October 5, 2019, <https://codes.iccsafe.org/content/chapter/15773/>.

SUPPORTING POLICIES AND ACTIONS

In order to enter the mainstream market, electric vehicles must be broadly seen as affordable, convenient, and practical by consumers. As electric vehicles tend to face an upfront cost penalty compared to conventional gasoline vehicles, financial incentive policies can be a major driver in encouraging adoption. Other non-financial policies aim to improve the convenience of electric vehicles, such as giving drivers preferred access to roadways, parking, or charging. Integrating ZEVs into public and private fleets helps to increase uptake, and also promotes greater awareness and acceptance of these technologies. This section outlines the diverse policies implemented at the local and national levels in these electric vehicle capitals.

Financial incentives. Financial incentives have been a crucial tool in the early electric vehicle market. Almost all electric vehicle sales to date have occurred in markets with financial incentives to reduce the upfront cost of the vehicles. These can take the form of rebates, bonus payments, or vehicle tax discounts or exemptions. These incentive programs are most commonly implemented at the national level rather than by cities; however, regional and local governments also provide incentives in some cases.

Table 1 below provides an overview of the financial policies applicable to privately purchased electric vehicles in each of the selected cities, including the estimated incentive value for a representative electric vehicle, as of mid-2018. Unless otherwise noted, the taxation policies are implemented at a national level. The listed incentive values and policies represent the government-provided benefit for a BEV relative to a comparable gasoline vehicle, including incentives, rebates, and differences in taxes; the values for PHEVs are frequently lower. Our representative vehicles are the Volkswagen e-Golf in Europe, the Nissan LEAF in Japan, the Tesla Model 3 in the United States, and the BAIC EC220 in China. These models were chosen because they were among the best sellers in their respective markets and represented characteristics typical of the vehicle market overall. Additional details on the incentives, and on how they are more complexly designed than shown here, can be found in supporting papers.¹⁴

14 Sandra Wappelhorst, Peter Mock, *Using vehicle taxation policy to lower transport emissions: An overview for passenger cars in Europe*, (ICCT: Washington, D.C., 2018), <https://theicct.org/publications/using-vehicle-taxation-policy-lower-transport-emissions>; Zifei Yang, Peter Slowik, Nic Lutsey, Stephanie Searle, *Principles for effective electric vehicle incentive design*, (ICCT: Washington, D.C., 2016), <https://theicct.org/publications/principles-effective-electric-vehicle-incentive-design>.

Table 1. Financial incentives for private passenger electric vehicles in 2018.

City	Purchase incentive policy	Value for representative vehicle ^a
China cities ^b	National subsidy up to ¥66,000; local subsidy up to ¥33,000; Exempt from purchase tax and annual vehicle & vessel tax	¥42,000 (\$6,300)
Oslo and Bergen, Norway	Exempt from value-add tax and registration tax	NOK 140,000 (\$15,600)
Paris, France	Bonus-malus system with up to €6,000 bonus for BEVs; exemption from regional registration tax	€5,000 (\$5,500)
London, United Kingdom	£4,800 bonus payment; exemption from registration tax and ownership tax	£3,300 (\$4,075)
Amsterdam, Netherlands	Exempt from registration and ownership taxes	€6,050 (\$6,700)
Stockholm, Sweden	National bonus-malus system, up to SEK 60,000 bonus for BEVs; 3-year exemption from annual ownership tax	SEK 25,750 (\$2,650)
Tokyo, Japan	National subsidy up to ¥400,000; local subsidy up to ¥300,000; exemption from national tonnage and vehicle registration taxes	¥806,000 (\$7,400)
U.S. cities ^c	Up to \$7,500 federal tax credit; up to \$2,500 state tax credit (in California or New York)	\$9,000

^a Representative vehicles are Volkswagen e-Golf in Europe, Nissan LEAF in Japan, Tesla Model 3 in the United States, and BAIC EC220 in China

^b Includes Shanghai, Beijing, Shenzhen, Hangzhou, Tianjin, Guangzhou, Zhengzhou, Chongqing, Wuhan; Other cities of Qingdao, Weifang, Nanchang have lower subsidies totaling ¥30,000-¥35,000 (\$4,500-\$5,300)

^c Includes Los Angeles, San Francisco, San Jose, and San Diego, California and New York, New York. Federal rebates have been reduced for some companies in 2019 which is after the analysis period of this paper

Some jurisdictions also provide significant incentives and tax benefits for electric vehicles purchased by companies for private or fleet use, especially in Europe, where such vehicles make up a substantial share of new vehicle sales.¹⁵ Additional incentives are available in some cities for low-income drivers, those in specific municipalities or neighborhoods, or those participating in scrappage schemes; these specialized incentives are not included here.

Since mid-2018, several jurisdictions have modified their incentive schemes. Notably, China announced changes to its subsidies for new energy vehicles in March 2019, which reduced national subsidies by more than 50% and prohibited local subsidies, instead encouraging cities to support the growth of charging infrastructure.¹⁶ Additionally, the United Kingdom reduced its plug-in car grant for BEVs from £4,500 to £3,500 and ended the grant for PHEVs in October 2018.¹⁷ In the United States, tax credits of up to

15 Sandra Wappelhorst, Peter Mock, Zifei Yang, *Using vehicle taxation policy to lower transport emissions: An overview for passenger cars in Europe*, (ICCT: Washington, D.C., 2018). Retrieved from <https://theicct.org/publications/using-vehicle-taxation-policy-lower-transport-emissions>

16 Hui He, Hongyang Cui, *China announced 2019 subsidies for new energy vehicles* (ICCT: Washington D.C., 2019). <https://theicct.org/publications/china-announced-2019-subsidies-new-energy-vehicles>

17 Office for Low Emission Vehicles, "Changes to the Plug-in Car Grant" (Department for Transport, 2018), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/753151/picg-end-of-transition-2018.pdf

\$7,500 are progressively reduced for manufacturers after they reach 200,000 electric vehicle sales; this led to the tax credits being reduced for Tesla in September 2018 and for General Motors in January 2019.¹⁸

Non-financial incentives. In addition to financial incentives, governments can increase the attractiveness of electric vehicles by making them more convenient to own than other vehicles. Leading cities around the world have created numerous programs in this vein to fit local context.

Several major cities in China, including Shanghai, Beijing, Shenzhen, Tianjin, Guangzhou, and Hangzhou, have set limits on new car registrations in order to tackle increasing congestion and air pollution. New car licenses are distributed through an auction (as in Shanghai), a lottery (as in Beijing), or a combination (as in Shenzhen). These quotas represent a significant impediment to licensing a new gasoline vehicle: Only 1 in 2,000 applications received in Beijing in 2018 was approved, whereas the cost through the auction in Shanghai reached about 88,000 yuan (\$13,300). In each of these cities except for Beijing, there is no limit on the number of electric vehicles that can be registered, offering an electric vehicle buyer a substantial advantage compared to purchasing a gasoline vehicle. In Beijing, a separate quota is also imposed on new electric vehicles.

A number of cities also give electric vehicles priority to road space, such as bus or carpool lanes. In California, zero-emission vehicles have access to the state's network of high-occupancy vehicle lanes for three years after the initial purchase, including along major highways in the Los Angeles, San Francisco, San Jose, and San Diego metropolitan areas. Electric vehicles also received free access to the express lanes on several highways in these cities, although they now receive a discounted rate as of 2019. As a different approach, many cities in China, such as Beijing, Tianjin, and Zhengzhou, restrict vehicles from driving in central urban areas one day per week based on license plate number, but the cities exempt electric vehicles from these restrictions.

Parking benefits also serve as valuable incentives for electric vehicles in many of the electric vehicle capitals. In some cities, such as Amsterdam, this takes the form of priority in obtaining residential parking permits. In other cities, electric vehicles receive free parking in public lots or along streets, either for a limited amount of time (2 hours in Shenzhen) or for an unlimited period (San Jose and Paris). In still other cities, such as Los Angeles and Qingdao, certain preferential spots are set aside for electric vehicles, making it easier for them to secure parking in congested areas.

Planned zero-emission areas. As cities plan to significantly cut transportation-sector pollution, several have announced plans to curtail internal combustion engine vehicles' access to the city through the introduction of zero-emission areas (ZEAs). Five of these cities, Paris, London, Los Angeles, Oslo, and Tokyo, have signed the Fossil Fuel Free Streets Declaration, pledging to make a major area of their city zero-emissions by 2030. Amsterdam has declared that the central city will be accessible only to zero-emission vehicles by 2025, and plans to extend this status to the entire city by 2030. Oslo and Bergen have both set earlier targets: Oslo's city center will be fossil-free by 2024 and Bergen is introducing a zero-emission zone in 2020 and

¹⁸ EVAdoption, Federal EV Tax Credit Phase Out Tracker By Automaker, accessed October 5, 2019, <https://evadoption.com/ev-sales/federal-ev-tax-credit-phase-out-tracker-by-automaker/>

expanding it city-wide by 2030.¹⁹ In August 2019, China's Ministry of Industry and Information Technology (MIIT) officially announced its support for proper cities and provinces in China to set pilot fossil-fuel-vehicle-free areas. Such planned restrictions send a clear signal to businesses and residents to consider electric vehicles in their purchasing decisions.

Electrification of shared fleets. Shared fleets operating in cities offer promising applications for the early deployment of electric vehicles. Vehicles in taxi, ride-hailing, or car sharing fleets often have higher annual mileage than private cars, enabling greater operational savings. As these vehicles are used by many people, they also have potential benefits in terms of raising awareness and education around electric vehicles.

Most of the electric vehicle capitals in this study have initiatives to introduce electric vehicles into shared fleets, particularly cities in China. By the end of 2018, 99% of the approximately 22,000 taxis operating in Shenzhen were electric, representing about 13% of the electric cars in the city. Shenzhen also has taken strong steps to electrify its ride-hailing fleet. On September 16, 2019, the revised draft of Shenzhen's Tentative Measures on the Management of Ride-hailing Vehicle Operations and Services was approved, which requires all newly-registered ride-hailing vehicles in Shenzhen be BEVs.²⁰ Other cities are now also electrifying their taxi fleets: Beijing had approximately 4,000 electric taxis deployed in August 2019 and plans to electrify 30% of its taxi fleet, equal to 20,000 electric taxis, by 2020;²¹ Guangzhou has over 3,000 electric taxis in operation by April 2019 and expects to achieve a 100% electric taxi fleet in the coming 2-3 years.²² Outside of China, London is making substantial progress in electrifying their black cab fleet through the introduction of the custom-designed LEVC TX, with a target of 9,000 to be deployed by 2020. London is also working with ride-hailing company Uber to make all vehicles operating on the platform in the city electric by 2025. New York City has capped the number of for-hire vehicles, such as Uber and Lyft, allowed to operate but battery electric vehicles are exempted from the cap.²³

Electric car sharing has also grown in popularity in the electric vehicle capitals. Each of the 13 electric vehicle capitals in China have at least one electric car-sharing service. EVCARD, the Shanghai-initiated electric car-sharing program, has now extended its service to 39 Chinese cities, with more than 50,000 electric vehicles in operation. Each of the four capitals in Europe also has electric car sharing. Notably, Amsterdam has 3 all-electric car sharing services (Buurauto, Car2Go, and Fetch by Renault). Nissan launched the e-share Mobi program in several cities in Japan, including Tokyo, in early 2018 with the LEAF electric car. Among the four cities in the United States, where car sharing is less popular, only Los Angeles had an electric car-sharing service, Blue LA, using the Bolloré Bluecar, which launched in 2017.

19 Norwegian EV Association. Elbilhovedstaden 2019, accessed September 25, 2019, https://elbil.no/wp-content/uploads/2019/08/Endelig_versjon_Elbilhovedstaden-2019_Rapport_web.pdf.

20 Shenzhen Special Zone Daily, "Shenzhen revises Tentative Measures on the Management of Ride-hailing Vehicle Operations and Services [深圳修订网约车经营服务管理暂行办法]," accessed September 25, 2019, http://www.sz.gov.cn/cn/xxgk/zfxxgj/zwdt/201909/t20190917_18213638.htm.

21 Yuhan Dong, "30% of taxis will be zero emission vehicles by the end of 2020 [2000辆换点出租车8月上路 2020年底三成出租车零排放]," *Beijing Daily*, August 17, 2019, <http://www.beijing.gov.cn/fuwu/bmfw/jtcx/ggts/t1596980.htm>.

22 Xueying Chen, "Guangzhou popularizes battery electric taxis [广州市全面推广纯电出租车]," *Xinhuanet*, April 30, 2019, http://www.gd.xinhuanet.com/newscenter/2019-04/30/c_1124439658.htm.

23 New York City Taxi & Limousine Commission, FHV vehicle license pause explainer, accessed September 25, 2019, https://www1.nyc.gov/assets/tlc/downloads/pdf/pause_explainer_final.pdf.

Electrification of city fleets. Cities can lead in the transition to electric vehicles by electrifying their own fleets, which typically include a wide variety of light- and heavy-duty vehicles. Electric vehicle capitals are taking advantage of this opportunity to reduce operating costs while also promoting electric vehicles to the public. All of the electric vehicle capitals have significant electric vehicle targets for their light-duty vehicles, and many have deployed significant numbers of vehicles. New York City has over 2,200 electric passenger vehicles in its fleet and has set a new target of 4,000 by 2025; the city has experienced maintenance cost savings of 65% for its electric cars compared to gasoline cars.²⁴ Paris had approximately 400 electric cars in its city fleet in 2018, but plans to have 90% of its fleet electric, or 1,500 vehicles, by 2021. Many cities in China require a certain percentage of new-purchased government vehicles be electric. For example, the current percentage requirement in Shanghai is 80%.

In addition to their leadership on electric passenger vehicles, most of the electric vehicle capitals have committed to electrifying their bus fleets. Figure 4 illustrates the targets set among the 25 cities for fully converting their bus fleets to zero-emission electric or hydrogen vehicles. Overall, 20 of the 25 cities have targets for the full conversion of the bus fleet to zero emissions either at the city, state, or national level. The remaining five, Bergen, Paris, Stockholm, Tokyo, and Weifang, have either not formally set a year for 100% conversion of the fleet, or plan to include other alternative fuels in their bus fleets indefinitely. In addition, many of the cities have also committed to procuring only zero-emission buses from 2025 onwards.²⁵



Figure 4. Target years for full conversion of bus fleets to zero-emissions in electric vehicle capitals.

Shenzhen is the first major city in the world to fully convert its bus fleet to electric, completing the task in 2018. Guangzhou, with more than 11,000 electric buses in operation, has also almost finished the conversion.²⁶ To comply with the electric bus deployment target of the Chinese central government, all the other electric vehicle capitals from China, with the exception of Weifang, are expected to finish the conversion no later than 2020. Outside of China, targets for conversion of the bus fleet range from 2025 in Amsterdam to 2040 in New York City. San Diego and San Jose also plan to convert their bus fleets by 2040 to comply with a California statewide mandate. Most of these cities have some electric buses in operation as of 2019, with tens of

24 “New York City Doubles EV Fleet Goal to 4K,” *Government Fleet*, May 20, 2019, <https://www.government-fleet.com/332241/new-york-city-doubles-ev-fleet-goal-to-4k>.

25 C40 Cities, “Our commitment to green and healthy streets,” accessed October 6, 2019, <https://www.c40.org/other/green-and-healthy-streets>. Cities in Figure 4 include Amsterdam, London, Los Angeles, Oslo, Paris, Tokyo.

26 Guangzhou Municipal Government, “Electrify Guangzhou’s bus fleet [推动广州市公交电动化工作],” (February 15, 2018), <http://www.gz.gov.cn/gzgov/2018rw269/201808/aeec562ea6bf42dd9b8f00340a5c23f2.shtml>.

thousands in operation across China. Outside of China, the numbers are much smaller but are growing: 100 are running in Amsterdam, Oslo has also purchased 100,²⁷ and 24 hydrogen buses serve parts of the San Francisco metropolitan area.²⁸

Furthermore, a number of cities are introducing electric trucks. Shenzhen is a leader in this space as well and has deployed nearly 62,000 electric trucks as of the end of 2018, most of which are light-duty delivery trucks.²⁹ The city's newly-released target requires all new engineering vehicles, such as dump trucks, sanitation trucks, and concrete mixer trucks, be electric by 2021.³⁰ Beijing has also deployed hundreds of electric sanitation trucks. Additionally, London, New York, Los Angeles, San Diego, and Oslo are also testing electric garbage trucks in small numbers.

Summary of incentives by city. Each of these electric vehicle capitals has achieved success through a combination of different incentives at the national and local level. Table 2 below summarizes twelve of the key policies implemented by leading governments around the world. For each action, we consider if the action is implemented in each electric vehicle capital by the local government (X), a state or national government (O), or at multiple levels of government (⊗).

27 Sustainable Bus, Electric bus, main fleets and projects around the world, accessed September 20, 2019, <https://www.sustainable-bus.com/electric-bus/electric-bus-public-transport-main-fleets-projects-around-world/>.

28 AC Transit, The HyRoad, accessed September 20, 2019, <http://www.actransit.org/environment/the-hyroad/>.

29 ESCN, "Which market is the benchmark of new energy vehicle promotion and application in China [谁是中国新能源汽车推广应用市场的“示范标杆”]," ESCN, October 18, 2019, <http://escn.com.cn/news/show-775841.html>.

30 Bureau of Industry and Information Technology of Shenzhen, "Shenzhen Action Plan on Promoting the Development of New Energy Engineering Vehicle Industry (2019-2021) [深圳市推进新能源工程车产业发展行动计划(2019-2021年)]," (July 4, 2019) http://www.sz.gov.cn/cn/xxgk/zfxxgj/tzgg/201907/t20190704_18035560.htm.

Table 2. Summary of promotion actions in place in electric vehicle capitals.

Country	Metropolitan area	Planned zero-emission area	Exemption from vehicle licensing restriction	Purchase incentive	Charging station incentives	EV-ready building and parking codes	Priority road access	Parking benefits	Electric taxi promotion	Electric car-sharing	City fleet electrification goal	100% zero emission bus target	Consumer awareness program
China	Shanghai		×	⊗	⊗	×		×	⊗	×	×	○	×
	Beijing			⊗	⊗	×	×		⊗	×	×	○	×
	Shenzhen		×	⊗	⊗	×	×	×	⊗	×	×	⊗	×
	Hangzhou		×	⊗	○	×	×		⊗	×		○	×
	Tianjin		×	⊗	○	×	×	×	⊗	×	×	○	×
	Guangzhou		×	⊗	⊗	×			⊗	×		⊗	×
	Qingdao			○	○	×		×	⊗	×		○	×
	Zhengzhou			⊗	○	×	×	×	⊗	×	×	○	×
	Changsha			⊗	○	×		×	⊗	×		○	×
	Weifang			○	○	×		×	⊗	×			×
	Nanchang			○	⊗	×	×	×	⊗	×		○	×
	Chongqing			⊗	⊗	×	×	×	⊗	×		○	×
	Wuhan			⊗	⊗		×	×	⊗	×		○	×
Japan	Tokyo	×		⊗	⊗				×	×			
Norway	Oslo	×		○	×	×	×	×	×	×	×	×	○
	Bergen	×		○	×	×	×	×	×		×		○
France	Paris	×		○	×			×	×				
United Kingdom	London	×		○	○	×	×	×	×	×			
Netherlands	Amsterdam	×		○				×	×	×	×	×	
Sweden	Stockholm			○	⊗					×	×		×
United States	Los Angeles	×		○	○	○	○			×	×	⊗	×
	San Francisco			○		⊗	○				×	⊗	×
	San Jose			○		○	○	×			×	⊗	×
	San Diego			○		○	○				×	○	×
	New York			○	○	×	○				×	×	×

× = action by local government; (○) = action by state or national government; (⊗) = action at multiple levels

As shown in the table, most of these policies are implemented in several cities, illustrating that cities are embracing similar electrification paths and likely learning

from each other, as many coordinate through international platforms and bilateral engagement. Shenzhen, Tianjin, and Oslo, three of the cities with the greatest growth in electric vehicle sales, led with 11 of the 12 actions in place. Two other cities—Shanghai and Zhengzhou—followed with 10 actions each. Twenty of the 25 cities had at least 7 actions in place.

To illustrate how cities are successfully implementing these diverse actions, Table 3 provides examples of an exemplary policy in each category from one of the electric vehicle capitals. These examples are either especially notable or have a track record of success. However, each policy is adapted to the specific conditions and authorities in each city, making it difficult to directly compare policies.

Table 3. Highlighted electric vehicle support policies and programs.

Policy area	Selected city	Policy description
Planned zero-emission area	Amsterdam	City center open to zero-emissions transport only by 2025
Exemption from vehicle licensing restriction	Shanghai	Zero-emission vehicles exempted from costly auction for new vehicle licenses
Purchase incentive	Hangzhou	City government subsidy of up to ¥33,000 (\$5,000) for new electric vehicle
Charging station incentives	Beijing	Annual subsidy of up to ¥200,000 (\$30,000) for charging stations
EV-ready building and parking codes	Bergen	All new or remodeled indoor parking spaces must be EV-ready, as well as a share of outdoor spaces
Priority road access	Oslo	Electric vehicles have access to bus lanes, discounts on tunnel and ferry fees
Parking benefits	Paris	Free parking for electric vehicles at public spaces (up to a week)
Electric taxi promotion	Shenzhen	Full conversion of taxi fleet of over 21,000 vehicles to battery electric
Electric car-sharing	Shanghai	Subsidize car-sharing companies electric vehicle purchases and subsidize the construction and operation of charging infrastructure for car-sharing
City fleet electrification goal	New York City	Over 2,200 electric cars in city fleet; all new cars purchased by city as of 2018 must be electric
Zero emission bus target	Guangzhou	Completed conversion of fleet to 11,000 battery electric buses in 2019
Consumer awareness program	Los Angeles	Multiple informational websites, events, and campaigns from city, regional agencies, utilities, and NGOs

Many of the top electric vehicle markets, especially those that have had the highest electric vehicle uptake, have begun to revise their electric vehicle promotion policies to address market conditions in 2019. Many cities in China, directed by the central government, have removed city-level financial incentives for electric vehicle purchases. In Oslo, bus lane access for electric vehicles has been reduced to selected days of the week, and electric vehicles are no longer provided free parking and charging.

California has tightened eligibility for electric vehicles to drive in carpool lanes to a period of three years, and electric vehicles will soon have to pay a discounted toll rate, rather than being totally exempt from tolls. Stockholm has phased out their free parking policy for electric vehicles. On the other hand, some other policies like building codes and fleet electrification targets are becoming more stringent to support a larger number of vehicles as vehicle technology costs continue to fall.

TRENDS AMONG THE WORLD'S ELECTRIC VEHICLE CAPITALS

Over the past four years, the electric vehicle market has rapidly expanded around the world, yet many of the same cities have continued to lead in terms of electric vehicle uptake and associated policies. By analyzing additional trends among these cities, other dynamics are revealed regarding markets' movement to higher electric uptake.

Figure 5 shows how the top 20 electric vehicle markets have shifted in terms of the global rankings for highest cumulative electric vehicles for years 2016, 2017, and 2018. These 20 cities are among the largest and most active electric vehicle markets, which have each been featured in several research reports.

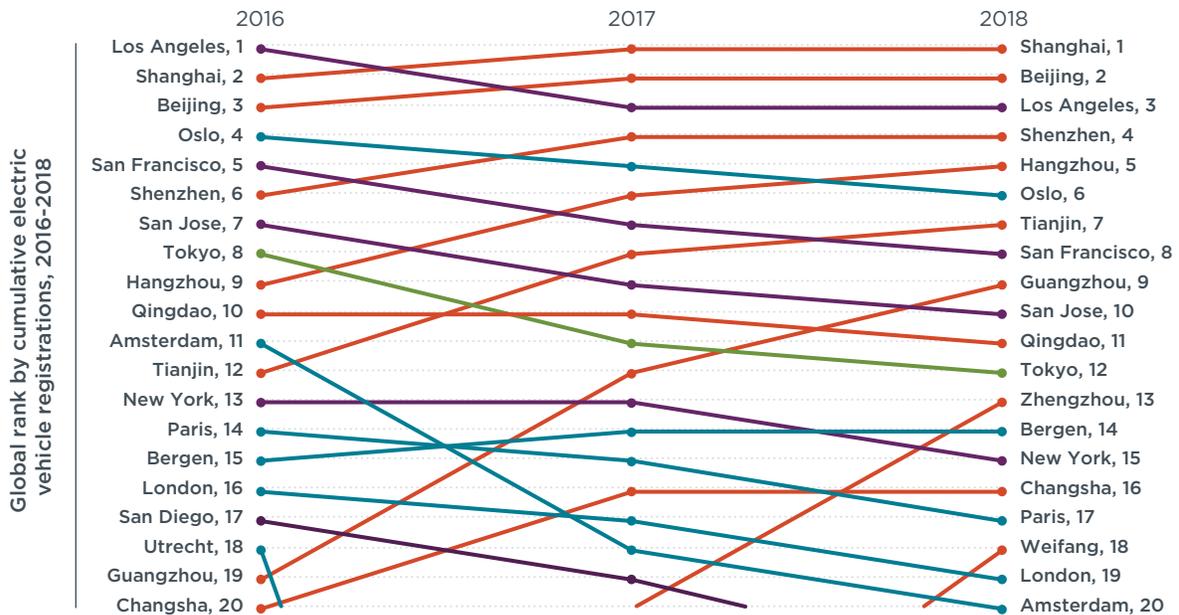


Figure 5. Global ranking of electric passenger vehicle stock from 2016-2018.

Figure 5 clearly illustrates the rapid ascension of cities in China as the largest electric vehicle markets. While the largest cities in China placed second, third, sixth, and ninth in terms of cumulative electric vehicle sales in 2016, 4 of the 5 largest electric vehicle markets in 2018 were in China. This trend seems likely to continue, considering the size of these cities' markets, their growing vehicle populations, and the continued policies there. However, also shown, the highest rankings changed less dramatically from 2017 to 2018 compared to the previous year.

For a selection of top electric markets in each major region, trends in electric shares and annual new electric vehicle are further analyzed. Figure 6 illustrates the growth in

electric vehicle shares of new vehicles for four markets in China, four in Europe, and three in the United States. As indicated, most of the markets have experienced steady growth since 2016; eight of the eleven surpassed a 10% electric share by 2018, and three surpassed 20%. The most notable exception to the steady growth is Amsterdam, which changed its incentive program in 2016 to shift the incentives to primarily spur BEVs but saw a return to strong growth in 2018. Shown to the right side are the consumer market categories from the Rogers’ “diffusion of innovation” framework,³¹ where the first 2.5% of the market are “innovators,” followed by the next 13.5% as “early adopters,” and the following 34% as the “early majority.” Within this framework, the diffusion of electric vehicle technology in most markets around the world is still largely in the innovator category. But in the local markets of Oslo, San Jose, Shenzhen, and Tianjin, electric vehicle adoption is progressing past early adopters into the early majority of new vehicle buyers.

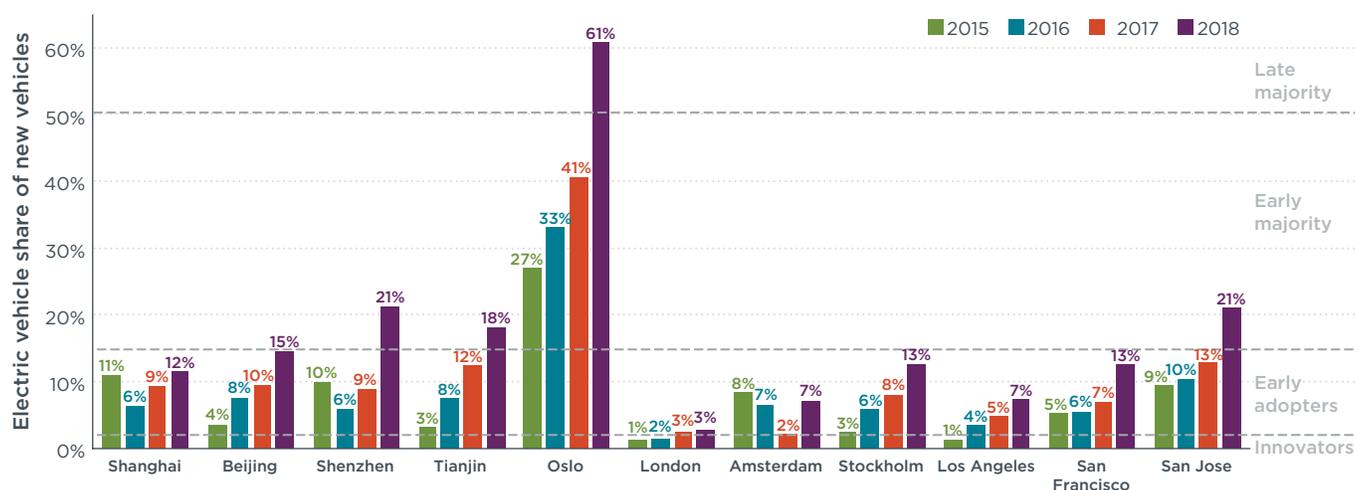


Figure 6. Electric vehicle share of new vehicles in selected metropolitan areas for 2015-2018. (Electric vehicle registration data are from IHS Markit, Norsk Elbilforening, and China Automotive Technology and Research Center)

Figure 7 shows the electric passenger vehicle sales for the same selected eleven cities for years 2015 to 2018, showing the top markets by cumulative electric sales in each region (again, four in China, four in Europe, and three in the United States). The darker colors at the bottom of each bar represent BEV sales, while the lighter colors at the top represent PHEV sales.

31 Everett M. Rogers, *Diffusion of innovations*, (Free Press of Glencoe: New York, 1962)

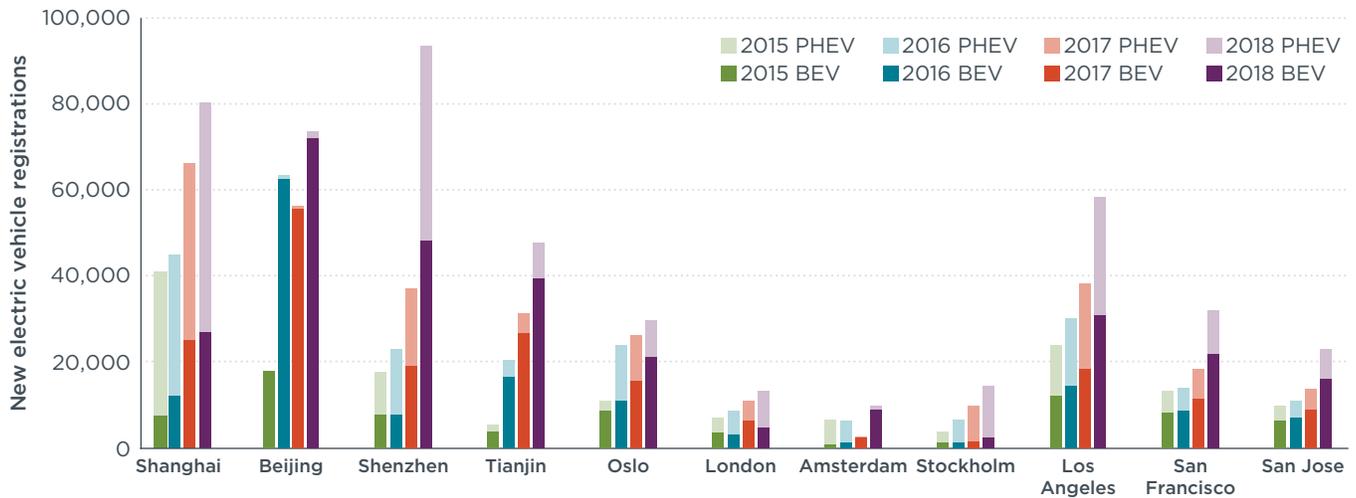


Figure 7. New electric vehicles in selected metropolitan areas, showing mix by plug-in hybrid electric vehicle (PHEV) and battery electric vehicle (BEV) for 2015-2018. (Electric vehicle registration data are from IHS Markit, Norsk Elbilforening, and China Automotive Technology and Research Center)

Several observations can be made from Figure 7. First, although these cities have in general seen strong growth in electric vehicle sales, this growth has taken different paths. The electric vehicle growth has been most dramatic in Chinese cities, as China's electric vehicle production volume has grown to become about half of global production over this period. In some cities, electric vehicle sales in absolute number have fallen, but at a slower rate than the decline in the overall market. In fact, the electric vehicle sales share has increased even as sales volume has declined, as in Beijing with 10% in 2017 versus 8% in 2016. Such situations could eventually become more common where cities seek to limit overall car ownership to improve congestion and air quality, while simultaneously promoting the electrification of the remaining fleet. Out of these selected cities, Tianjin shows the fastest annual growth, increasing by 870% in three years (compared to about a 260% increase globally over the same period). This success is, to a great extent, attributable to Tianjin's comprehensive set of fiscal and non-fiscal support policies and its relatively open market environment with many available electric vehicle models.

There is also a general trend away from PHEVs toward BEVs in most cities. Based on overall light-duty passenger electric vehicle sales globally, the BEV share has gradually grown from 63% in 2016, to 65% in 2017, to 69% in 2018. Many of the major electric vehicle markets have experienced a similar trend toward BEVs. In Amsterdam, the PHEV-dominated market collapsed in 2017 following a change in the incentives to prioritize BEVs, and BEV sales surged in 2018. In the United States, Japan, and Shenzhen in China, sales have generally shifted toward BEVs as well. BEVs have consistently dominated in the Beijing (98-99% BEVs) and Tianjin (over 80% BEV) markets. In contrast, PHEVs have held a steady share of the London and Shanghai markets (with about two thirds of new electric vehicles) and Stockholm (about 85%).

While the order of the top electric vehicle markets has changed, the relative concentration in the most successful metropolitan areas has remained relatively constant. Through 2018 the top 25 metropolitan areas contained 42% of the world's passenger electric vehicle stock; that same metric was 45% for 2017. The top 10 cities

alone accounted for 22% of the world’s electric vehicles in 2018; through 2017, the top 10 cities accounted for 29% of all electric vehicles. In the future, as electric vehicles continue to proliferate into more markets around the world, the distribution seems likely to broaden further.

CONCLUSIONS

Globally, the electric vehicle market is growing quickly but remains a small component of the transportation landscape. However, leading cities around the world are developing policies and implementing promotion programs to overcome the barriers to passenger electric vehicle adoption. These top electric markets are providing a first look at how mainstream electric vehicle markets are emerging, and the associated policies offer a guide for other cities to learn from and tailor policies to their own market.

This briefing assessed the continued growth and development of new policies in the 25 largest electric vehicle markets in 2018, which we term electric vehicle capitals. As shown in Figure 8, the 25 markets, with data analyzed at the metropolitan area-level, made up 42% of the global passenger electric vehicle sales through 2018. At the same time, these areas represent only 4% of the world’s population and 10% of the new passenger vehicle market. As shown, 13 of the 25 markets are in China, followed by six in Europe, five in the United States, and one in Japan.

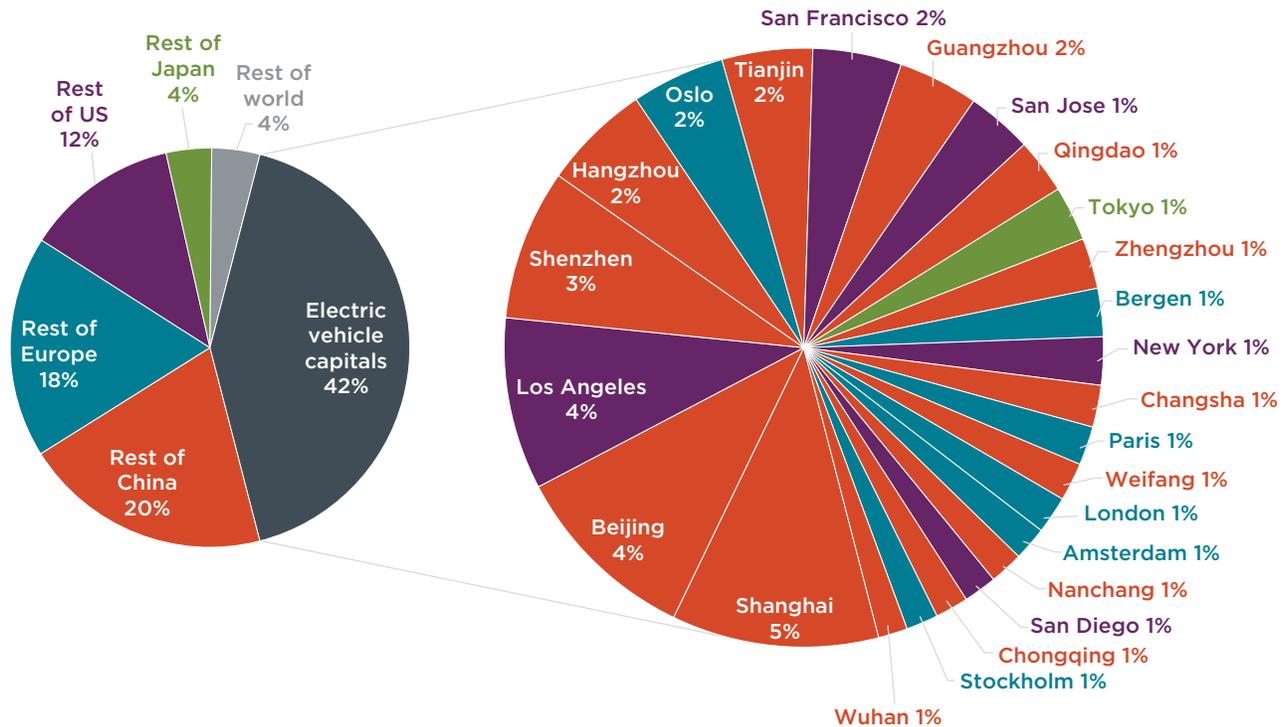


Figure 8. Global electric vehicles in 25 electric vehicle capitals as a share of the global electric vehicle stock.

From this research, we make the following three conclusions.

Cities in China continue to be the largest markets globally. Cities in China represent 5 of the 6 largest electric vehicle markets by cumulative electric vehicle sales. The top 13 markets in China have accounted for one quarter of all the electric vehicles sold globally through 2018—and more than in all of Europe or the United States during that period. In particular, Shanghai, with the most cumulative electric vehicle registrations, Shenzhen, with the most electric vehicle registrations in 2018, and Beijing, with the most cumulative and 2018 battery electric vehicle registrations, have implemented novel policies, developed massive charging infrastructure networks, and provided generous incentives to accelerate electric vehicle uptake. Other cities in China have followed with similar promotion actions to achieve high electric shares, such as Tianjin, Weifang, and Liuzhou (each with over 15% sales share in 2018).

Cities adapt as electric vehicles enter the mainstream. The top electric markets are quickly moving from early adopters to the mainstream consumer. The 25 top electric markets, and nearly all global electric vehicles, are in China, Europe, Japan, and the United States, which all have regulations to ensure increasing electric vehicle model availability over time. Twelve of these 25 cities had an electric vehicle sales share of over 10% in 2018. The cities are adjusting their policies to reflect this market growth, with several taking steps to phase out cost-intensive policies like purchase incentives and toll exemptions. At the same time, cities are developing strong policies to assure the continued shift to electric vehicles, such as licensing restrictions on internal-combustion vehicles, zero-emission areas, and electrification requirements for public and private fleets. Cities are also continuing to expand charging infrastructure to keep pace with the electric vehicle market, including adopting EV-ready building codes to reduce the long-term costs.

As the global market grows, the role of the top cities remains crucial. As the global market has grown from under 1 million electric vehicles sold in 2015, to over 5 million through 2018, and over 7 million through late 2019, the top 25 metropolitan areas have consistently accounted for over 40% of the global electric vehicle stock. However, there are signs that the market is becoming less concentrated. The top 10 cities identified in this year's study represented a lower share of the global stock in 2018 than in previous years. As battery costs fall, electric vehicle production expands to more markets, and more governments set electric vehicle targets, the policies from electric vehicle capitals are increasingly being adopted by more, and by smaller, cities looking to emulate leading markets. As electric vehicle sales grow worldwide, the lessons from these leaders will continue to be vital for governments to smoothly orchestrate the transition to the mainstream market.