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Evaluating the top electric vehicle markets in the world

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Summary

We analyze the highest-growth electric vehicle uptake markets, focusing on the 25 metropolitan areas globally with the highest cumulative passenger electric vehicle sales. These 25 areas in China, Europe, Japan, and the United States account for 44% of cumulative global electric vehicle sales, despite accounting for only 12% of the passenger vehicle market and less than 4% of the population. We find these markets each have a suite of national and local programs that help to overcome the prevailing electric vehicle barriers of affordability, convenience, availability, and awareness to enable the early market success.

Keywords: market development, policy, infrastructure, government, mass market

1 Introduction

Over 1 million new plug-in electric passenger vehicles were sold worldwide in 2017, and targets from both automakers and governments indicate far greater volumes in the coming years. While electric vehicles accounted for only 1% of new passenger vehicle sales worldwide in 2017 and 2% in 2018, a number of markets are seeing considerably higher sales. Nearly all electric vehicles to date have been sold in China, Europe, Japan, and the United States, where regulations spur industry and a combination of programs to overcome cost, convenience, and awareness barriers. Norway led in shares, with plug-in vehicles representing nearly half of passenger vehicle sales in 2018. China led in overall volume with more than a million passenger electric vehicle sales in 2018.

The transition to electric vehicles remains concentrated in particular areas, spurred by policies at all levels of government. Within the top electric markets, certain metropolitan areas exemplify the multi-pronged approach to promoting electric mobility, implementing carefully tailored policies at multiple levels. In 2016, 20 cities accounted for 43% of global electric vehicle sales [1].

In this paper, we identify with the metropolitan areas around the world with the highest cumulative electric sales through 2017. We then analyse these 25 areas' electric vehicle sales through 2017, which we refer to as electric vehicle capitals: Beijing, Changsha, Chongqing, Guangzhou, Hangzhou, Qingdao, Shanghai, Shenzhen, Tianjin, Wuhan, and Zhengzhou, China; Paris, France; Tokyo and Kyoto, Japan; Amsterdam, Netherlands; Stockholm, Sweden; London, United Kingdom; and Los Angeles, New York, San Diego, San Francisco, San Jose, and Seattle, United States.

Although the markets are named by their major cities, we use data that include the broader surrounding metropolitan areas to reflect the reginal nature of policy and travel. We analyze markets at the metropolitan

area level due to the regional nature of household travel patterns, charging infrastructure, and policy, as well as for more consistent global comparisons.

2 Analysis of electric vehicles, charging infrastructure, and policy

2.1 Electric vehicle sales

Based on our assessment of vehicle sales and new vehicle registrations datasets from all the foremost electric vehicle markets, we identified the 25 metropolitan areas with the highest cumulative electric vehicles from 2011 through 2017. These 25 electric vehicle markets each had over 20,000 electric vehicle sales through 2017. Our preliminary results indicate that these 25 cities combine for over 1.3 million electric vehicle sales, or 44% of the global total. At the same time, these cities account for less than 12% of the global passenger vehicle market and less than 4% of the global population. Beyond the 25 cities highlighted in this paper, we find that 37 cities account for half of global electric vehicle sales to date.

Figure 1 shows cumulative electric vehicle sales from the top 25 markets, including a breakdown according to all-electric battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). Shanghai led the world with over 162,000 cumulative electric vehicle sales since 2011 (over 5% of the global total), followed by Beijing and Los Angeles with over 140,000 cumulative sales. Seven additional cities also have over 50,000 cumulative electric vehicle sales: Shenzhen, Oslo, Hangzhou, San Francisco, Tianjin, San Jose, and Qingdao. Bergen and Oslo had by far the highest electric shares, with electric vehicles accounting for 50% and 40% of passenger vehicle sales, respectively.

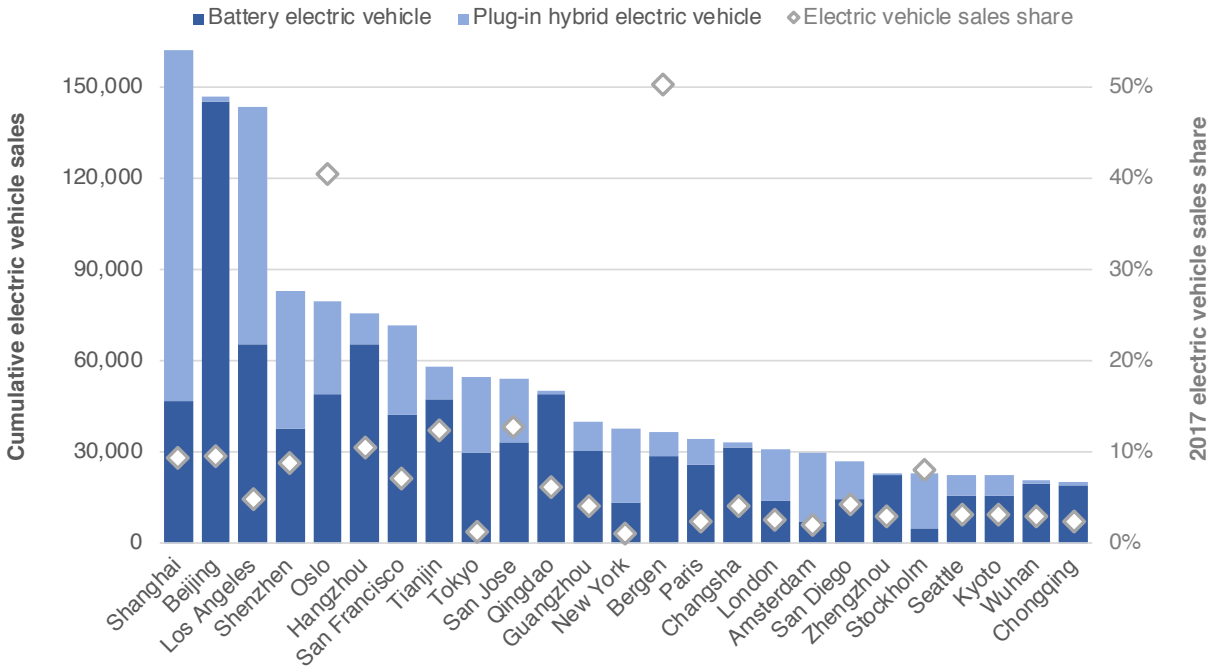

Figure1: Cumulative electric vehicle sales and 2017 electric vehicle sales shares in the top electric vehicle cities

The electric vehicles in these different markets vary as a result of financial and nonfinancial incentives, model availability, and consumer preferences. In Beijing, Changsha, Zhengzhou, Wuhan, Chongqing, and Amsterdam, electric vehicle sales in 2017 were almost exclusively BEVs. This reflects subsidies that target purely electric vehicles, and also BEV-targeted preferential registration and road access in Beijing. In Stockholm and other cities, registrations were primarily PHEVs, where they benefit more heavily from national taxation policies. In many cities in China, such as Chongqing and Qingdao, electric vehicle sales are dominated by local manufacturers due to local policies that target the region's major electric vehicle producer.

These top markets all typically benefit from high electric vehicle model availability from many automakers resulting from supportive policies in place, as discussed below.

2.2 Charging infrastructure

Electric vehicle charging infrastructure is a key enabler and driver of the transition to electric vehicles, and electric vehicle capitals havetypically led in the deployment of charging infrastructure within their regions [2]. Figure 2 the amount of publicly available electric vehicle charging infrastructure in each electric vehicle capital as of the end of 2017. The bars show the number of charge points per million population, including fast and regular charging speeds. A primary finding from this assessment is that, despite the high variability, these markets have much more charging infrastructure than elsewhere. On average, these 25 markets have 24 times the public charging per capita of the rest of the world (i.e., 699 versus 25 charge points per million residents), and 20 of these 25 markets have 10 times the charging per capita of the rest of the world. Together, the 25 electric vehicle capitals are home to 40% of the world's public charging. The data for Zhengzhou and Wuhan are estimated based on provincial-level counts.

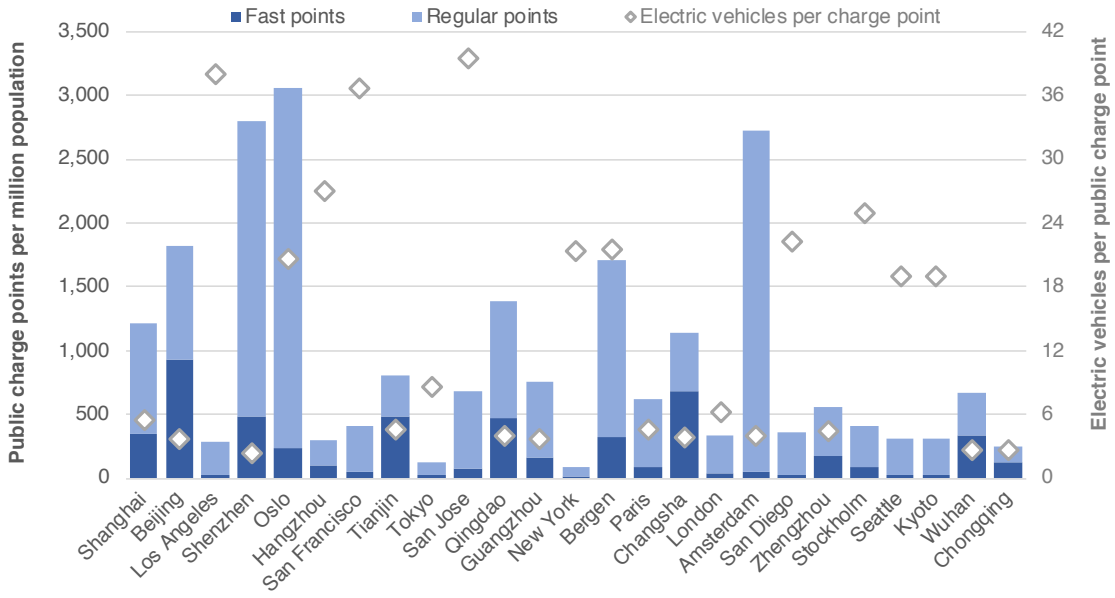

Figure2: Public electric vehicle charging infrastructure (regular and fast) per million population and per electric vehicle in the electric vehicle capitals

As shown in Figure 2, the deployment of this charging infrastructure varies significantly across these top markets. The variation reflects housing and parking patterns, urban form, demographics, and electric vehicle fleet composition [2]. Measuring charging on a per capita basis does not reflect differences in car ownership rates (e.g., New York has relatively low car ownership compared to other U.S. cities). The data points in the figure, corresponding to the right axis, show the ratio of electric vehicles per public charge point to provide another comparative benchmark. In absolute terms, cities in China tend to have the most public electric vehicle charging infrastructure, led by Beijing at 39,000 charge points and Shenzhen with 35,000, and they also had the highest share of fast charging. Cities in the United States tend to have less public charging per capita and have the highest ratio of electric vehicles to public charging, as more drivers there have access to private home charging. Many electric vehicle capitals also have substantial workplace charging installed. San Jose has the highest amount of workplace charging among U.S. cities at almost 900 charge points per million population.

To accelerate the construction of sufficient charging infrastructure and maximize investment, several electric vehicle capitals have created strategic plans and deployed unique strategies. Beijing has released the highest target, with plans to build more than 435,000 chargers by 2020, with targets for other cities ranging from 15,000 (Wuhan) to 210,000 (Shanghai) in the same year [3]. Amsterdam's program to build public charging

stations based on driver-reported demand has created one of the most comprehensive charging networks in Europe and has been replicated in several other Dutch cities. New York has committed to construct fast-charging hubs in each borough in 2018 with the capacity to charge 12,000 vehicles per week with 50 such hubs by 2020. Shenzhen is working not only to accelerate the pace of charging station construction, but also to upgrade older charging stations to add additional charge points per station, increase power, and add smart-charging capabilities to distribute power based on vehicle need and grid conditions [4]. Seattle seeks to promote construction of curbside charging stations by public and private entities, a prevalent practice in Amsterdam and also in London.

2.2.1 Charging infrastructure incentives

In addition to setting targets and building public charging stations, top electric vehicle markets also are assisting drivers and businesses in purchasing and installing charging infrastructure. The Tokyo Metropolitan Government provides subsidies for the cost and installation of charging infrastructure in multi-unit dwellings, where 60% of the population lives, and is providing support and outreach to speed up deployment in this sector. The governments of Oslo and Paris also provide funding for charging at apartment buildings, with Oslo providing 20% of the costs up to about $600 per charge point and Paris providing 50% up to 4,000 euros per building. All of the 11 electric vehicle capitals in China provide subsidies for charging infrastructure deployment. For example, Shanghai subsidized 30% of the total investment of specialized and public chargers. Chongqing offered a subsidy of 300 yuan ($44) per kilowatt to regular chargers and 600 yuan per kilowatt for fast chargers. .

2.2.2 Building and parking codes.

Beyond today's charging infrastructure, electric vehicle capitals are setting the stage for a complete transition to electric vehicles, where charging infrastructure will need to be nearly universal. This can be accomplished through building codes that mandate charging infrastructure, or wiring to enable easy installation, in new buildings and parking structures. Oslo, where electric vehicles already represent 10% of the cars on the road, requires 50% of parking spaces in new developments or expansions to have charge points, with the remainder being "EV ready" with appropriate electric wiring and capacity [5]. In London, 20% of parking spaces at all new developments must come with fully functional charge points, with make-ready infrastructure at additional spaces [6]. San Francisco now mandates make-ready wiring for 100% of parking spaces in all new construction. The state of California in 2016 became the first in the United States to adopt EV-ready building codes. Many of the electric vehicle capitals in China (e.g., Beijing, Qingdao, Shanghai, Tianjin, Chongqing, Guangzhou, Shenzhen, Zhengzhou) mandate a certain percentage of newly built parking spots be equipped with charge points. Beijing requires that 20% of new parking spots of commercial buildings be equipped with chargers. The percentage requirements for new parking spots of residential buildings, office buildings, and other public buildings (e.g., hospitals, schools, stadiums) are 100%, 25%, and 15%, respectively. Qingdao mandates that 100% of new parking spots in residential buildings and 20% of new public parking spaces be equipped with chargers or include EV-ready wiring.

2.2.3 Utility charging infrastructure construction

In order to accomplish their ambitious charging infrastructure goals, pioneering cities frequently partner with electric power utilities. ConEd is partnering with New York City to build the previously mentioned fast charging hubs, while Nuon installs the curbside charging stations in Amsterdam's demand-based program. In some cases, utilities are becoming major drivers of the charging ecosystem. By the end of 2017, the State Grid built 7,200 public chargers in Beijing and was developing networks in key cities across the northern part of China. The China Southern Power Grid is constructing charging infrastructure in Guangzhou, Shenzhen, and other key cities in the southern part of China (more than 3,000 as of May 2018). The goal is to build 674 centralized charging stations and 25,000 distributed public charging points by 2020, with an investment of more than 3 billion yuan ($440 million). Empowered by the state utility authority, three major California utilities are planning to build thousands of charging stations, including many in the Los Angeles, San Diego, San Francisco, and San Jose areas. In the Los Angeles region, the Los Angeles Department of Water and Power and several smaller utilities also offer incentives for home and workplace charging stations. These utilities and their customers generally benefit from electric vehicles because of the additional revenue,

and by gaining an electric load that can be guided toward optimal times (e.g., overnight or when renewable electricity is being generated).

2.3 Electric vehicles in fleets

Passenger vehicles, responsible for the largest share of fuel use in the transport sector, are primarily privately owned. However, during early stages of the transition, fleets of many kinds can provide ideal opportunities for early electric vehicle penetration to improve scale, reduce air pollution, increase awareness and experience on charging projects, and provide lessons for mass market uptake. This has been the case in these electric vehicle capitals, where government fleet procurement and supportive policies have encouraged greater deployment of electric vehicles more broadly. The use of electric vehicles in fleets in these capitals includes government cars, transit, taxis, car-sharing, and emerging autonomous vehicle research.

2.3.1 City fleets

City-owned vehicles are typically the area where local governments have the greatest authority in selecting new vehicles. Many electric vehicle capitals have taken advantage of this authority and are quickly transitioning their city fleets to electric. A leader in this area, Stockholm has fully transitioned its 800-car city fleet. New York City operates more than 1,300 electric vehicles in its city fleet and has more than 500 dedicated charging stations [7], and the police department is also integrating electric vehicles. Forty percent of Seattle's light-duty fleet was electric by the end of 2017, and it expects to fully transition its city fleet by 2023. Many cities in China mandate that a certain percentage of new government vehicle purchases be electric. The existing requirements are 30% in Tianjin, 50% in Shanghai, 70% in Shenzhen, 80% in Zhengzhou, and 100% in Beijing.

2.3.2 Transit buses

Electric transit buses have experienced growth similar to electric cars, bolstered by lower battery costs and urban air quality concerns. This is particularly the case in China, where there were about 385,000 electric buses, more than 99% of the global total, in 2017 [8]. Several electric vehicle capitals in China have made substantial progress in electrifying their bus fleets. They are led by Shenzhen, which has completely transitioned its fleet of more than 16,000 buses to electric, the first and largest city in the world to accomplish this task. Other cities also have made substantial progress. Guangzhou had more than 2,500 electric buses in service by the end of 2017 and plans to complete the transition to electric by the end of 2018 [9]. Changsha owned 5,080 electric buses by the end of 2016, accounting for 80% of its bus fleet, and aims for a full shift to electric by the end of 2020 [10]. Ninety-three percent of Zhengzhou's 6,420-bus fleet is electric, and the whole fleet is expected to be electric by the end of 2020 [11]. Lessons on the operation, infrastructure needs, and cost-effectiveness of these buses are enabling smaller cities to follow in the paths of these electric vehicle capitals.

Outside of China, other cities also have begun to deploy electric buses, albeit at a slower pace. Many cities in Europe and North America have procured their first several dozen electric buses and are investigating how quickly to go to all electric. Amsterdam hosts the largest electric bus fleet in Europe with 100 articulated battery electric buses and expects to fully transition its fleet by 2025. As of September 2018, 26 cities of the Fossil-Fuel-Free Streets Declaration, including electric vehicle capitals Paris, London, Los Angeles, Oslo, Seattle, and Tokyo and others across Australia, Canada, Europe, Latin America, South Africa, and the United States, have pledged to procure only zero-emission buses starting in 2025.

2.3.3 Taxis and ride-hailing

Taxis and ride-hailing vehicles account for a sizable share of vehicles, vehicle-miles traveled, and pollution in urban areas. Governments are prioritizing these vehicles in the transition to electric mobility in order to realize outsized benefits in air pollution and fuel consumption [12]. Several cities in China are close to the ambitious goal of completely electrifying their taxi fleets. Shenzhen had 13,000 battery electric taxis in service as of May 2018. The existing 7,500 gasoline taxis are all required to be replaced by battery electric

vehicles by the end of 2018 to achieve complete transition to electric. Furthermore, Shenzhen has mandated that all new registered ride-hailing vehicles be battery electric from August 2018 [13]. All new taxis and ride-hailing vehicles must be electric in Beijing and Tianjin, a policy that started in 2017. Guangzhou mandates that at least 80% of new taxis be battery electric in 2018 and plans to achieve a fully electric taxi fleet by 2022 [14].

Similarly, London is swiftly transitioning its iconic fleet of black cabs to plug-in hybrid vehicles, with a target of 9,000 on the road by 2020. Oslo plans to have a fully zero-emission taxi fleet by 2022.

Ride-hailing fleets also are beginning the transition to plug-ins in electric vehicle capitals. Ride-hailing company Uber will require all new drivers in London to use electric cars by 2019 and will transition its entire fleet no later than 2025; the company is providing incentives of up to 5,000 pounds to encourage the switch. In the United States, Uber has launched pilot programs in cities including Los Angeles, San Diego, San Francisco, and Seattle that will pay drivers extra for driving electric and provide resources to promote the technologies. In China, Didi Chuxing has 260,000 electric vehicles registered in its ride-hailing platform as of early 2018, a number expected to increase to 1 million in 2020 [15]. To support this transition, Didi Chuxing has developed dedicated charging networks for these ride-hailing vehicles in collaboration with Teld, a major charging infrastructure operator. Other ride-hailing companies in China are making similar strides; for example, Shou Yue has deployed thousands of electric vehicles in Hangzhou, Guangzhou, and other cities. Cao Cao also has more than 10,000 electric cars in service across various cities.

2.3.4 Car-sharing

Most of the top electric vehicle-uptake cities operate car-sharing programs, and several of these cities have sought to electrify these fleets. Electric vehicle capitals in China tend to lead in this field. In Shanghai, the EVCard service includes more than 7,700 electric vehicles. EVCard has now expanded to 17 other cities in the Yangtze River Delta. Similar services exist in the other leading cities, such as United Journey in Shenzhen; Gofun and Yidu Yongche in Beijing; PonyCar in Guangzhou; Panda Auto in Chongqing; Yibu Yongche in Zhengzhou; as well as Chefenxiang in Hangzhou.

Electric car-sharing operations have attracted interest and faced setbacks in some areas. Bolloré operated the Autolib' car-sharing program in Paris since 2011 with approximately 4,000 purpose-built electric cars; however, this service was ended in 2018. Nonetheless, similar programs operated by the same company have been opened in London and Los Angeles, as well as in other cities in France. The Norwegian State Railways opened a new electric car-sharing program in Oslo with 250 vehicles in 2018. In other cases, major auto manufacturing companies have created electric vehicle-focused shared fleets, including Daimler's car2go in Amsterdam, BMW's ReachNow in Seattle, and Nissan's e-share mobi in Tokyo.

2.3.5 Autonomous vehicles

Many of the electric vehicle capitals highlighted in this briefing also are leaders in the push for autonomous vehicles. Furthermore, in many cases, these cities are encouraging the development of electrified autonomous vehicles, supported by major companies and enabled by the rich electric vehicle ecosystems in place. In San Francisco, both Waymo (a project of Google parent Alphabet) and Cruise Automation (owned by General Motors) are testing autonomous technologies on electric car platforms. Likewise, Baidu is testing autonomous electric vehicles in Chongqing, and startup Nio is developing its smart vehicle system in Shanghai. Beijing released the first autonomous vehicle testing regulation in China in December 2017 and set aside two road segments for testing. Shanghai followed Beijing with its testing regulation in March 2018 and provided SAIC and Nio with special license plates for testing. Tokyo plans to introduce electric, autonomous shuttles for the 2020 Olympics.

2.4 Supporting actions and policies

Electric vehicle capitals have supported the deployment of electric vehicles through a wide array of local policies and actions, while also benefitting from regional and national support. Numerous studies have examined the impact of local actions within different regions [16-18]. Although specific authorities and conditions in cities vary, electric vehicle capitals consistently have used similar tools to reduce barriers of

cost, convenience, and awareness for electric vehicle adoption. In this section we discuss some of the most common actions, including financial incentives, licensing and registration policies, parking policies, and consumer awareness campaigns. We also provide examples of their implementation in these leading cities.

2.4.1 Financial incentives

During the early stages of the transition, the high cost of batteries means that electric vehicles typically have higher upfront costs than comparable internal combustion engine models. For that reason, financial incentives are one of the most effective tools in promoting electric vehicle uptake. In many jurisdictions, these are implemented at the national level (e.g., China, United States, Norway) or regional level (e.g., California, Québec) in the form of upfront rebates, tax exemptions, or pollution-indexed taxation. However, local governments also offer incentives in some regions to further boost the electric vehicle market.

Many cities in China offer incentives for electric vehicles in addition to the national government's incentive, which amounts to 20,000–40,000 yuan ($2,900–$6,400) depending on the vehicle's range. This includes the country's electric vehicle capitals: Zhengzhou offers the largest value at approximately 26,400 yuan ($3,800) for a long-range BEV, whereas Beijing, Shanghai, Shenzhen, Guangzhou, Tianjin, Hangzhou, and Wuhan offer 22,000 yuan ($3,200) for a similar car. Incentives generally are higher for longer-range vehicles, and some cities also give lower incentives for micro-cars. The Tokyo Metropolitan Government offers tax breaks for electric vehicles, as well as additional incentives for commercial vehicles and taxis.

In total, long-range electric vehicles receive purchase incentives of up to 62,000 yuan ($9,000) in the leading cities in China. That compares to $10,000 in federal and state incentives for BEVs in California cities, up to 4,500 pounds ($5,900) from the national government in the UK, and tax benefits that can be 3 to 5 times higher in Norway. In combination with the other policies, these incentives are an effective tool in lowering the upfront cost barrier and expand access to a broader market of potential buyers as battery costs continue to decline. Also, several cities (including Paris and Beijing) offer targeted incentives for the replacement of older vehicles with electric vehicles, as part of scrappage schemes.

2.4.2 Licensing and road access benefits

The ability to preferentially grant licenses and road access privileges in China has been a dominant policy in driving uptake in the early market [19]. Through 2017, six out of the 11 electric vehicle capitals in China (Beijing, Shanghai, Shenzhen, Tianjin, Hangzhou and Guangzhou) offer vehicle registration privileges for electric vehicles. These six cities all imposed a cap on new license plates every year, with the aim of controlling vehicle stock to mitigate traffic congestion. New license plates are given out by lottery in Beijing, by auction in Shanghai, and by a combination of both in the rest of the cities. These six cities have used this license plate quota system to preferentially offer more licenses to electric vehicles. For example, Beijing set separate license plate lottery systems for BEVs and non-BEVs, with much higher odds for a license for BEVs. Shanghai offers a free license plate to electric vehicles, while combustion vehicles are subject to the auction, where average 2017 vehicle license plate was about 90,000 yuan ($13,000). In addition to these licensing policies, Beijing, Tianjin, Wuhan, Shenzhen, and Zhengzhou offer other road access privileges to electric vehicles. These cities restrict vehicles with license plates ending in specific numbers from particular roads on some days, but electric vehicles are exempted from these restrictions.

2.4.3 Parking benefits

Parking access, a valuable resource in dense cities, is used in a variety of ways to promote electric vehicles. A number of electric vehicle capitals provide free street or garage parking to electric vehicles in a variety of ways. Examples include Los Angeles (preferred spaces and free in certain cities), Oslo, Paris (up to 6 hours), San Jose (all municipal meters and garages), Shenzhen (1 hour of street parking), and Tianjin (1 hour of street parking). In some cases, electric vehicle drivers also are given priority for highly coveted residential parking permits, like in Amsterdam, Bergen, and Paris.

2.4.4 Lane access and fee exemptions

Cities have further promoted electric vehicles by allowing preferential access or reduced fees to use bridges, tunnels, high-occupancy vehicle (HOV) lanes, and bus lanes. These programs depend on local geography

and transportation policy but can generally provide valuable benefits to drivers at a low cost to the city. Such policies were pioneered in Norway, where local governments including Oslo and Bergen gave electric vehicles free access to tunnels, ferries, toll roads, and bus lanes. These programs have since been phased down as the popularity of electric cars there resulted in greater traffic. Such incentives have been implemented in many electric vehicle capitals. In the California cities of Los Angeles, San Diego, San Francisco, and San Jose, electric vehicles have access to HOV lanes and discounts on bridge tolls. In London, electric vehicles are exempt from the congestion charge in the central city. Electric vehicles are exempted from annual road and bridge tolls in the main districts of Chongqing, valued at 2,300 yuan ($330) per year. Wuhan exempts electric vehicles from bridge and tunnel tolls.

2.4.5 Consumer awareness programs

Even in leading regions, many people remain unaware or misinformed regarding electric vehicle availability, operation, incentives, and benefits. Leading cities, in conjunction with regional and national governments, utilities, manufacturers, and advocacy organizations, have created consumer awareness and education programs to improve knowledge and generate greater interest in electric vehicles. Since 2011, Shanghai has been designated an EV Demonstration City, and hosts an EV Demonstration Zone where businesses and visitors can learn about electric vehicles, take test drives, and discover emerging technologies. The zone is supported by manufacturers, the State Grid, universities, and the federal government. Amsterdam has taken a more broad-based approach, including the promotional campaign “Amsterdam elektrisch,” electric vehicle events, highly publicized integration of electric buses and taxis at the Schiphol Airport, and a comprehensive city website with real-time information about the city’s charging network. London, as part of the Go Ultra Low Cities Program, is working with several boroughs to create “Neighborhoods of the future” to promote and prioritize electric vehicles through novel means, including low-emission zones, charging infrastructure for commercial vehicles at markets, and programs at schools. Prominent U.S. programs are Veloz (in California), Drive Change Drive Electric (in seven Northeastern states), and Electrify America (nationwide).

2.4.6 Zero-emissions zones and bans

As electric vehicle uptake continues to grow and emissions reductions become more urgent, leading cities are contemplating the next step of the transition to zero-emissions: removing combustion vehicles from the city. Paris, London, Los Angeles, Oslo, Seattle, and Tokyo, along with 20 other cities, have signed the Fossil-Fuel-Free Streets Declaration pledging to make a major part of the city zero-emissions only by 2030. London specifically has announced more ambitious goals, planning zero-emissions town centers by 2020 and a larger zero-emissions zone in central London by 2025. Other cities have even set dates for the complete transition to zero-emissions: Amsterdam has set a goal of 2025, and Paris 2030, although the applicable policies are not yet determined. Cities such as Beijing in China, as indicated above based on licensing and driving restrictions, appear to be moving along this path. Additionally, several countries home to electric vehicle capitals have announced plans to allow only electric vehicle sales after certain dates: Norway targets 2025 and the UK and France target 2040, whereas many U.S. states have indicated no later than 2050.

Table 1 summarizes many different city-level actions discussed in the sections above that are promoting the deployment of electric vehicles in major markets around the world. The table lists many of the prominent actions and policies in place by category and provides a leading example among the electric vehicle capitals, as well as a list of other cities with a similar policy in place. This table illustrates that this diverse group of cities has implemented many similar policies, indicating that cities continue to observe the developments and successes from elsewhere and deploy similar approaches in their own jurisdictions. On the other hand, some notable policies are in place in only a couple of cities, typically due to rarer and more specific authority over particular policies in those markets.

Table1. Overview of city-level policies in electric vehicle capital cities

Category	Program	Leading city	Leading policy	Other examples
Charging infrastructure	City charging strategy	Beijing	Target of 435,000 charge points by 2020, coordination with private partners and State Grid	New York, Oslo, Shenzhen, Shanghai, Tianjin, Guangzhou, Zhengzhou, Qingdao, Chongqing, Wuhan, Hangzhou, Changsha, London, Seattle, Tokyo
	On-demand public charging	Amsterdam	Demand-based allocation of curbside charging fulfilled by utility	
	Charging infrastructure incentives	Tokyo	Large incentives for charging stations at public and multi-unit dwellings	Oslo, Paris, Beijing, Shanghai, Shenzhen, Guangzhou, Tianjin, Hangzhou, Zhengzhou, Qingdao, Wuhan, Chongqing, Changsha
	Building and parking requirements	Beijing	100% of new residential parking spots and 20% of new commercial parking spots must have chargers	Qingdao, London, Shanghai, Tianjin, Chongqing, Guangzhou, Los Angeles, San Francisco, San Jose, Shenzhen, Zhengzhou, Oslo
	Utility partnerships	Guangzhou	Utility construction of smart charging stations	Amsterdam, Los Angeles, New York, Beijing, Shanghai, Shenzhen, Tianjin, Hangzhou
Fleets and new mobility	Taxis	Shenzhen	All new taxis must be electric as of 2017	Amsterdam, London, Oslo, Beijing, Tianjin, Guangzhou
	Electric ride-hailing	London	Only electric ride-hailing by 2025; Uber providing incentives	San Francisco, San Diego, Seattle, Shenzhen
	Electric autonomous testing	San Francisco	Electric autonomous vehicle testing by two leading companies	Beijing, Shanghai, Chongqing, Tokyo
	City fleet	Stockholm	Complete conversion of city car fleet	New York, Seattle, Beijing, Shenzhen, Zhengzhou, Shanghai, Tianjin, Oslo
	Buses	Shenzhen	Complete transition of 16,500 buses	Guangzhou, Tianjin, Changsha, Zhengzhou, Amsterdam
	Car-sharing fleet	Shanghai	Thousands of vehicles in multiple popular all-electric car-sharing fleets	Chongqing, Shenzhen, Beijing, Hangzhou, Guangzhou, Zhengzhou, Oslo, Amsterdam, Los Angeles
Supporting actions	Purchase incentives	Zhengzhou	Offering large upfront subsidies to electric vehicles (as much as 26,400 yuan in 2017)	Beijing, Shanghai, Shenzhen, Guangzhou, Hangzhou, Tokyo
	Preferential registration	Shanghai	Electric vehicle drivers receive free license plate, avoiding auction system for conventional vehicles	Beijing, Tianjin, Shenzhen, Guangzhou, Hangzhou
	Parking benefits	San Jose	Free parking on street and at municipal garages	Amsterdam, Bergen, Paris, Shenzhen, Tianjin, Oslo
	Toll exemptions	Oslo	Exemption from toll road, bridge, and tunnel charges	Bergen, New York, San Francisco, Chongqing, Wuhan
	Lane access	Bergen	Access to bus lanes	Los Angeles, Oslo, San Francisco, San Jose, San Diego
	Consumer awareness programs	Shanghai	EV demonstration zone with test drives, exhibits, and engagement with manufacturers and utilities	Amsterdam, Beijing, Los Angeles
	Planned zero-emission zones	London	Zero-emission town centers by 2020 and city center by 2025	Los Angeles, Oslo, Paris, Seattle

3 Conclusions

This review of electric vehicle sales, infrastructure, and supporting policies in leading electric vehicle cities leads us to the following reflections and lessons. Nearly half of the world's electric vehicles are in 25 cities. As of the end of 2017, these 25 cities were home to nearly 1.4 million of the world's 3.1 million passenger electric vehicles. These 25 cities, representing just 12% of world passenger vehicle sales, account for 44% of the world's cumulative electric vehicle sales through 2017. Figure 3 places these cities' electric vehicles in

the context of the global electric vehicle fleet. These markets strive to accelerate the shift to electric vehicles to improve air quality, meet their climate goals, and boost economic development for the new technology. These cities provide policy templates for other cities at earlier stages of the transition to electric mobility.

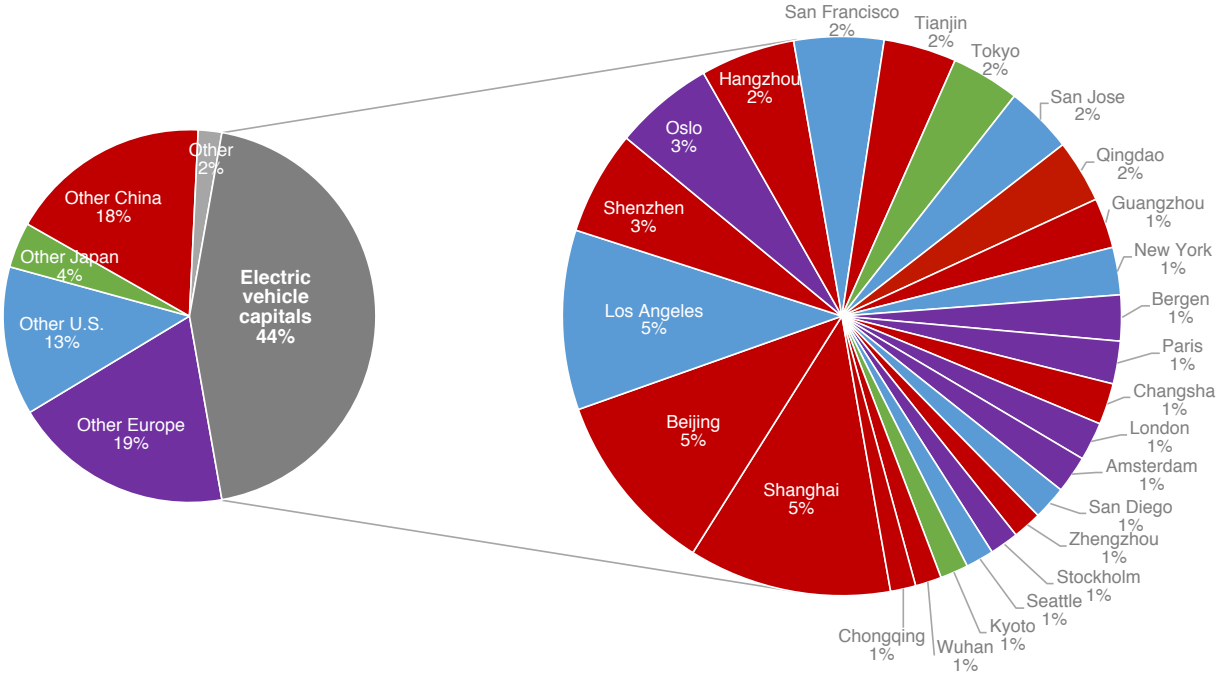

Figure3. Global electric vehicles in 25 electric vehicle capitals as a share of the global electric vehicle stock

The electric vehicle market is accelerating, with China leading the way. The global passenger electric vehicle market continues to grow. Global electric sales increased by more than 50% from 2016, to about 1.2 million in 2017, and 2018 sales will be far higher. The growth has been greatest in China, with half the global electric market and 11 of the 25 top global electric vehicle markets. Major cities like Beijing and Shanghai stand apart by implementing strong policies not found outside China, including large incentives and licensing and registration privileges for electric vehicles, to simultaneously tackle congestion and air quality. Other leading markets in Europe and the United States have similar but less extensive versions of the incentives and policy approaches of China. Oslo, London, and Paris, for example, are using their own authorities with low-emission areas, programs to transition taxi and ride-hailing fleets to electric, and deploying more charging infrastructure to spur the transition to electric drive.

The top electric markets are beginning to solve the infrastructure challenge. Charging infrastructure is a key driver to ensure electric vehicle driver confidence and convenience. Electric vehicle capitals use multi-faceted strategies and engage electric utilities and other charging providers to invest in infrastructure. Top electric vehicle-uptake cities provide incentives to catalyze the emergence of new business models, help construct fast-charging depots, and adopt building and parking codes to ensure broad access to charging over the longer term. The top 25 electric vehicle markets have, on average, about 24 times the available charging per capita as elsewhere. However, charging availability varies greatly among leading markets, with cities in China, the Netherlands, and Norway having greater levels of public charging per capita. This suggests that different markets are likely to take different approaches to develop their ideal charging infrastructure with a mix of home, workplace, public, and fast charging.

A comprehensive policy package is necessary to launch the electric market. Despite their many benefits, electric vehicles face diverse barriers. Top markets have implemented a host of policies to tackle all the barriers. Nearly all global electric vehicles (98%) are in China, Europe, Japan, and the United States, which have regulations to ensure electric vehicle model availability, incentives to reduce vehicle price, infrastructure

to ensure convenience, and campaigns to educate consumers. Comprehensive local policies distinguish the top electric vehicle markets from the rest. Although Beijing and Shanghai have uniquely strong electric vehicle licensing policies, many cities in China, Europe, and the United States provide substantial financial and nonfinancial perks. Reduced bridge, tunnel, and ferry tolls in Bergen and Oslo have been popular benefits during the explosive growth there. Many cities are now investigating the use of combustion bans and zero-emission-only areas to propel electric vehicles into the mainstream.

Electric vehicle markets are growing and beginning to expand beyond the early adopters. This is promising in terms of the shift toward greater economies of scale, improved air quality, and decarbonization of transport. From the beginning, leading markets have played an outsized role in overcoming barriers for electric vehicles. In addition to helping nudge more mainstream drivers toward electric vehicles, the top markets are navigating the next set of electric vehicle frontiers, including promoting universal charging access, electrifying transit fleets, and linking electrification to shared and autonomous mobility. These topics provide rich opportunities for emerging businesses as well as the design of smart policies to accelerate the trend.

Many markets are not represented in this study. For example, markets in Canada, Germany, and South Korea also have begun to experience significant electric vehicle growth. Cities in these markets are enacting electric mobility policies that could perhaps propel them into the ranks of the electric vehicle capitals. Beyond these markets, cities in emerging economy markets, which often experience the worst effects of air pollution and climate change, could also look to capitalize on these developments and adopt similar policies. The more quickly that more markets act to similarly break down the prevailing electric vehicle barriers, the quicker the global transition to zero-emission mobility will be.

References

[1] D. Hall, H. Cui, & N. Lutsey, *Electric vehicle capitals of the world: What markets are leading the transition to electric?,* ICCT, https://www.theicct.org/publications/EV-capitals-of-the-world-2017, 2017

[2] D. Hall & N. Lutsey, *Emerging best practices for electric vehicle charging infrastructure,* ICCT, https://www.theicct.org/publications/emerging-best-practices-electric-vehicle-charging-infrastructure, 2017

[3] "30余省市补贴频频落地 充电桩进入"爆发时代:," [More than 30 provinces and municipalities subsidize deployment of charging piles] 21st Century Business Herald, https://new.qq.com/cmsn/20170810/20170810003874, 2017

[4] W. Fan, "新能源车充电"按需分配"深圳样本：2018年将进入"大爆发"元年？" [New energy vehicle "on-demand distribution" of charging in Shenzhen: Will 2018 be the first "big outbreak" year?] 21st Century Business Herald, http://industry.caijing.com.cn/20180118/4395833.shtml, 2018

[5] S. Portvik, Oslo – The EV Capital of the World, Agency for Urban Environment, City of Oslo, https://www.toi.no/getfile.php/1340831/mmarkiv/Forside%202015/compett-foredrag/Portvik%20-EV%20presentation%20T%C3%98I%2012.%20June.pdf, 2015

[6] Office of the Mayor of London, "Land for Industry and Transport Supplementary Planning Guidance," https://www.london.gov.uk/file/5275/download?token=2kudYJzP, 2012

[7] "NYC Fleet Newsletter, Issue 217," NYC Citywide Administrative Services, http://www.nyc.gov/html/dcas/downloads/pdf/fleet/NYC_Fleet_Newsletter_217_March_28_2018_500th_EV_Charger_Announcement.pdf, 2018

[8] A. O'Donovan, J. Frith, and C. McKerracher, "Electric Buses in Cities: Driving Towards Cleaner Air and Lower CO2," Bloomberg New Energy Finance, https://about.bnef.com/blog/electric-buses-cities-driving-towards-cleaner-air-lower-co2/, 2018

[9] L. Dan, "年广州公交车将基本完成电动化 " [Guangzhou will basically achieve a 100% electric bus fleet in 2018], Diandong, 2 May 2018, http://www.diandong.com/guangzhou/2018050282034.shtml

[10] C. Yonggang and C. Xin, "长沙新能源公交车占公交车八成，年减排二氧化碳近1.7万吨" [80% of Changsha's buses are electric, reducing nearly 17,000 metric tons of CO2 emissions every year], Hunan Daily, http://hn.people.com.cn/n2/2017/0526/c356325-30244707.html, 2017

[11] Y. Li and W. Haixia, 三年后郑州市公交车辆将全部“绿色出行”[Zhengzhou’s bus fleet will be green in three years], Xinhua Net, http://www.ha.xinhuanet.com/car/carnews/2018-05/26/c_1122890825.htm, 2018

[12] S.R. George and M. Zafar, Electrifying the Ride-Sourcing Sector in California, California Public Utilities Commission, *http://www.cpuc.ca.gov/General.aspx?id=6442457050*, 2018

[13] Shenzhen Municipal Government,“深圳蓝”可持续行动计划” [2018 “Shenzhen Blue” Sustainable Action Plan]. *http://www.sz.gov.cn/zfbgt/gzwj/gz_1/201805/t20180510_11830011.htm*, 2018

[14] Guangzhou Transportation Commission, 关于加快新能源出租车推广应用工作的通知 [Notice on Accelerating New Energy Taxi Promotion and Application Work]. *http://www.gz.gov.cn/gzjtjg/zcfg/201805/b72f537587164fe0bef1559059fe1aa2.shtml*, 2018

[15] Y. Jia, “滴滴与特来电合作建立网约车充电网” [Didi Chuxing collaborates with Teld to develop charging system for ride-hailing vehicles], Auto Home, https://www.autohome.com.cn/news/201802/913276.html, 2018

[16] P. Slowik & N. Lutsey, *The continued transition to electric vehicles in U.S. cities*, ICCT, https://www.theicct.org/publications/continued-EV-transition-us-cities-2018, 2018

[17] H. Cui, L. Jin, H. Zhou, J. Zhang, J. Zhang, X. Liu, & H. He, 中国城市新能源乘用车激励政策评估 [Evalutation of incentive policies for urban NEVs in China] ICCT, https://www.theicct.org/publications/evaluation-incentive-policies-China-urban-NEVs, 2017

[18] N. Fearnley, P. Pfaffenbichler, E. Figenbaum, & R. Jellinek, *E-vehicle policies and incentives - assessment and recommendations*, Institute of Transport Economics, https://www.toi.no/getfile.php?mmfileid=41187, 2015

[19] H. Cui, L. Jin, H. Zhou, J. Zhang, B. Zhang, X. Liu, & H. He, **中国城市新能源乘用车激励政策评估** [Assessment of electric car promotion policies in Chinese cities] ICCT, https://www.theicct.org/publications/evaluation-incentive-policies-China-urban-NEVs, 2018

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