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ASSESSMENT OF ELECTRIC CAR PROMOTION POLICIES IN CHINESE CITIES

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EXECUTIVE SUMMARY

In recent years, China surprised the world with the impressive growth of its electric vehicle fleet. The nation's electric vehicle market began to take off in 2013, with four consecutive years of aggressive growth. In 2017, new plug-in electric car sales in China contributed to almost half of the total sales worldwide. Behind this success were a series of top-down macro designs, strategies, and policies that have emerged in the last decade to support the leapfrogging of the country's automotive industry. Among them, a landmark national campaign of electric vehicle development called Ten Cities, Thousand Vehicles, launched in 2009, and its subsequent expansions have profoundly shaped the configuration of China's electric vehicle deployment today. Cities participating in this program, called new energy vehicle pilot cities, were qualified for substantial central subsidies and other preferential policies to develop their local electric vehicle markets. As of the end of 2016, 88 cities had joined the program and accounted for nearly the entire electric vehicle market in China.

This study comprehensively catalogues governmental actions that spurred the sales of electric cars in these cities and identifies the driving forces behind the success of the leading cities. Specifically, it includes detailed qualitative and quantitative analysis of subnational policy actions promoting electric cars and the actual market performance in the leading 30 cities in electric car sales. In addition, the subnational data also reveal some general patterns of electric car markets in China.

This analysis focuses on the passenger car sector and the 30 cities that showed commitment and early success in developing the electric cars. These 30 cities collectively represented 84% of the nation's electric car market. Figure ES 1 shows the number of electric car sales and their market penetration in the top 30 cities.

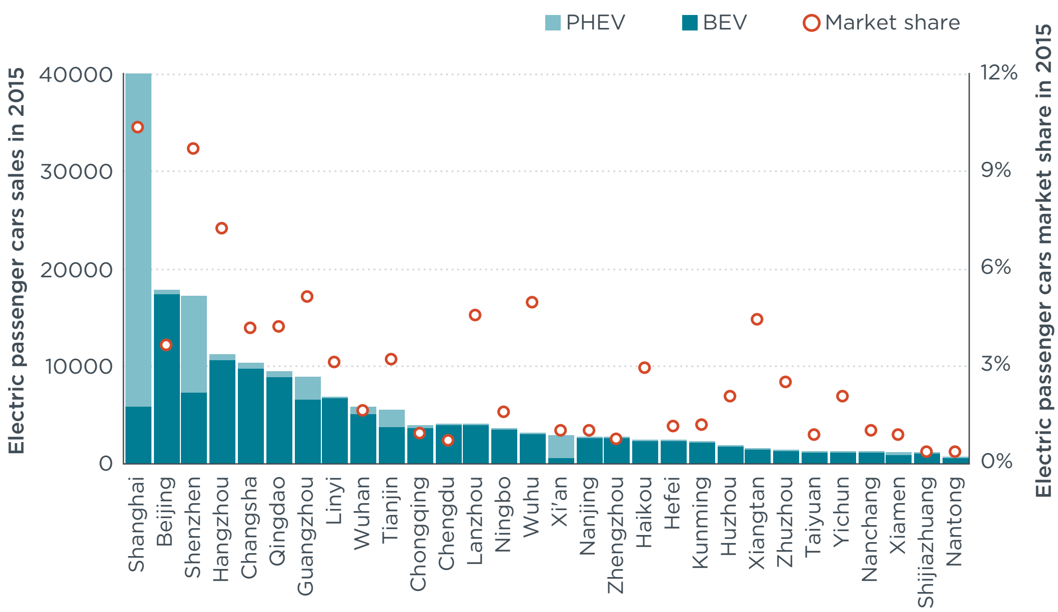

Figure ES 1. Electric car market size and penetration in 30 Chinese cities with leading electric car sales, 2015 (ordered according to total electric car sales).

Figures ES 2 and ES 3 compare monetized consumer benefits and market shares for each electric car technology in the same 30 cities. Among these, registration incentive, road access incentive, and the benefits from public charging infrastructure availability for battery electric vehicles (BEVs) are the main indirect incentives; the remaining are direct monetary incentives.

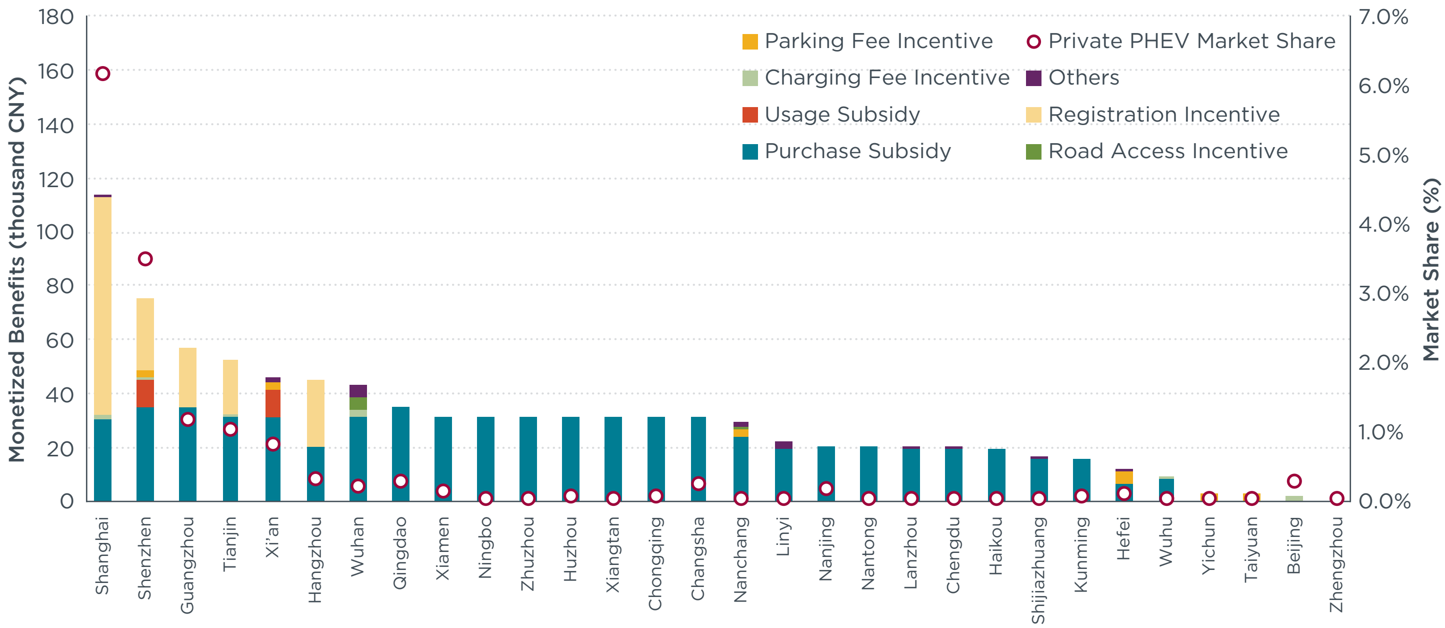

Figure ES 2. Private PHEV market share and monetized benefits to consumers (ordered according to the magnitude of monetized benefits provided to private PHEV consumers).

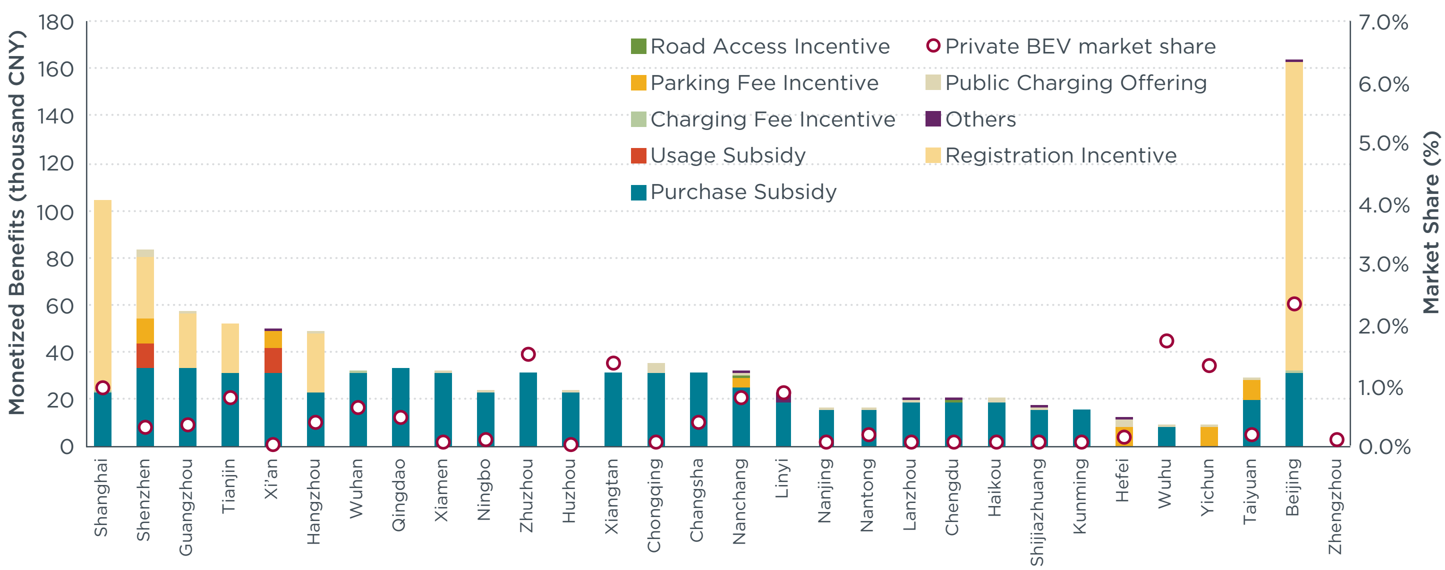

Figure ES 3. Private BEV market share and monetized benefits to consumers (ordered according to the magnitude of monetized benefits provided to private BEV consumers).

The assessment offers several main conclusions.

Cities were the frontier of pushing for electrification. Following China's top-down macro designs of its vehicle electrification advancement path, cities have been shouldering the major responsibilities in electric vehicle development from the very beginning. Guided by the central government, and sometimes provincial governments as well, cities develop goals and plans, and formulate and implement a suite of policies to support them. Cities also have been where the most innovative and aggressive policy measures have incubated and spearheaded. Of the 30 cities studied, 18 had set clear targets for electric vehicle deployment and charging infrastructure development. Some of the most powerful policy tools driving the electric car market included giving electric vehicle owners privilege in acquiring license plates and developing an electric vehicle-based urban micro public transit system, both of which were innovated and piloted in cities.

A comprehensive suite of policy actions was adopted by cities to promote electric cars. The 30 cities in our study deployed more than 20 policy actions, including direct subsidies and tax deductions—incentives that indirectly provide monetary value to consumers—and preferential measures for electric car fleet application. The most prevalent policies, adopted by more than 10 cities, were new vehicle purchase subsidies, exemption/reduction of annual vehicle tax for electric cars, and providing adequate charging facilities. Other major policies were car-sharing programs (nine cities), charging fee reduction (seven cities), license plate/registration privilege (seven cities), parking fee incentive (six cities), road access privilege (six cities), taxi fleet purchase incentive (five cities) and group purchase subsidy (five cities). Shenzhen and Xi'an were the most aggressive cities in government efforts promoting electric cars, in terms of the number of policy actions undertaken, with each having 10 policy actions.

Electric cars were being deployed disproportionately in the country. The top 30 cities represented only 26% of auto sales, but they made up 84% of electric car deployment in the entire country. In 2015, the average market penetration of electric cars in these cities was 2.7%, significantly greater than the national average of 0.8%. Great disparities were also found among the 30 cities, from over 10% electric car market penetration to below 1%. These evidences underscore the importance of city-based actions in promoting electric cars.

Various forms of fleet programs were the main driver of local electric car markets in many leading cities. Primarily determined by China's national strategies toward vehicle electrification, application of electric vehicles was first established in the civil service sector (buses, city sanitation, postal trucks) then gradually spread to fleet and private users. Sixteen cities in our study aggressively promoted electric car deployment in the fleet, which includes taxi, car-sharing fleets, and incentivized group acquisition and electric car rental. Electric cars in these 16 cities, on average, took up 4.4% of local new passenger car markets, higher than the average electric car market share of 2.7% for the 30 cities. In four cities—Hangzhou, Lanzhou, Shenzhen, and Guangzhou specifically—over 90% of BEVs were in the various fleets mentioned above. A few cities innovated a micro public transit program composed solely of electric cars, a variation of the mainstream car-sharing adopted in other parts of the world.

Incentives remain a key part of driving the private market for electrics. Greater monetary value of the full policy package offered in a city was found to evidently correlate with higher market share of private plug-in cars. The incentives include both financial and nonfinancial policy actions.

New vehicle registration incentives in mega cities were the major appeal to private consumers. In these 30 cities, direct vehicle purchase subsidies did little to explain the strength of the local electric vehicle market performance. Instead, we found that mega cities used new vehicle registration incentives, such as designating more license plates for new electric cars, as the major appeal to private consumers. Six cities in our study, namely Shanghai, Beijing, Guangzhou, Tianjin, Hangzhou and Shenzhen, adopted this policy. These cities imposed a limit, or cap, on total new vehicle registration to help relieve severe congestion. New vehicle owners must enter a lottery or auction system to be able to obtain a license plate, which has considerably increased the cost of owning a new car. Notwithstanding, in these highly urbanized and affluent cities, owning a car has become a way of life for many middle-class citizens. The stiff demand for new cars and increasingly precious license plate quota has largely driven up the explicit or hidden monetary value of a license plate to as high as 130,000 Chinese *yuan* ($19,000). This is more than the list price of a typical battery electric vehicle in China, which is to say, 19% higher than the price of a Zhidou E20, the best-selling BEV in these 30 cities in 2015. As cities were either exempting or treating electric cars preferentially in the license plate quota systems, electric car owners were enjoying this huge privilege that would save them money or time compared to buying a conventional car.

A comprehensive package of local policies is key to unlocking the electric car market. In this study, multiple indicators were examined to identify motives behind electric car uptake. A semi-qualitative rating against these factors across 30 cities showed that cities with the most comprehensive portfolio of actions to provide sufficient consumer incentives, enable and support fleet programs, expand consumer exposure to electric technologies, enrich model availability, ensure an open market, and charging convenience were experiencing greater success in accelerating the passenger car fleet to electrification. By comparison, cities strongly promoting one or two elements but missing other ingredients encountered a market deficiency of electric cars to various extents.

Manufacturers have seen fewer barriers in selling in their home markets. Despite the central government's relentless effort in forestalling local market protectionism since the initial design of its major policies toward electric vehicles, this study showed that the results were largely ineffective. In 16 of the 30 cities we studied, electric car markets were dominated by local brands. Local protection took many hidden forms, including customizing the qualification threshold for vehicle purchase subsidy with technical parameters that only local brands could pass.

This study also offers other valuable observations of electric car market patterns in China. We found that investment and resource allocation toward electric vehicles were more prominent in cities with potent political and economic influences, those often classified as Tier 1 or new Tier 1 cities. These cities tended to offer greater incentives to stimulate their electric car markets and often experienced greater EV adoption. Even though vehicle electrification was claimed as an antidote to urban air pollution in many Chinese regions, subnational data showed the connection between electric car uptake and local air pollution has yet to be established. Lastly, consumers in many smaller Chinese cities had a clear preference for micro battery electric cars.

This study points toward many unanswered questions that warrant frequent updates of similar assessment of electric car submarket data and local policy actions. Some cities in this report have been implementing substantial numbers of policies, but without yet seeing noticeable electric car deployment. Despite the strong correlation between consumer incentives and the private consumer market for plug-in hybrid cars, that link remains fuzzy for battery electric cars. In addition, demographics and income are important factors that were not explored in detail in this study. Finally, the charging infrastructure data in this study were largely incomplete, and therefore we are not ready to draw a clear conclusion regarding the contribution of charging facility availability to local electric car markets. However, our recent analysis of more than 350 metropolitan areas worldwide identified public charging infrastructure as statistically linked with greater EV uptake (Hall & Lutsey, 2017), which may warrant further investigation into the situation in China. In general, 2015 was a transitional year for the Chinese plug-in electric car market and many trends remain unclear. Updated data on new electric car sales, charging infrastructure, and other supplemental demographics in 2016 and later years will help better reveal those trends.

Electrification in the mobile source application is believed to be a promising solution for oil conservation, local air quality improvement, climate change mitigation, and industrial upgrading. Governments around the world have been acting progressively to overcome barriers and develop electric vehicle markets. Although the evolution of technology is an increasingly globalized process, market stimulation policies must be based primarily on local circumstances. Several major policy innovations by the Chinese cities studied and documented in this work add to the constantly growing global playbook of policies and contribute to finding the key ingredients to unlocking the electric vehicle markets in the remaining regions in China.

ACRONYMS

AC alternating current

BEV battery electric vehicle

DC direct current

EV electric vehicle

NEV new energy vehicle

PEC passenger electric car

PHEV plug-in hybrid electric vehicle

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1 INTRODUCTION

Since 2013, China has accomplished phenomenal growth of the so-called new energy vehicles (NEVs), namely battery electric, plug-in hybrid electric, and fuel cell vehicles (FCVs). With at least a 50% annual growth rate for four consecutive years, China emerges as an evident leader among major NEV markets globally. In 2016, China sold 336,000 plug-in electric cars (interchangeable with electric cars, which includes battery electric and plug-in hybrid electric vehicles), or 43% of the world's total (Figure 1). In 2017, new electric car sales in China contributed to almost half of the total sales worldwide.

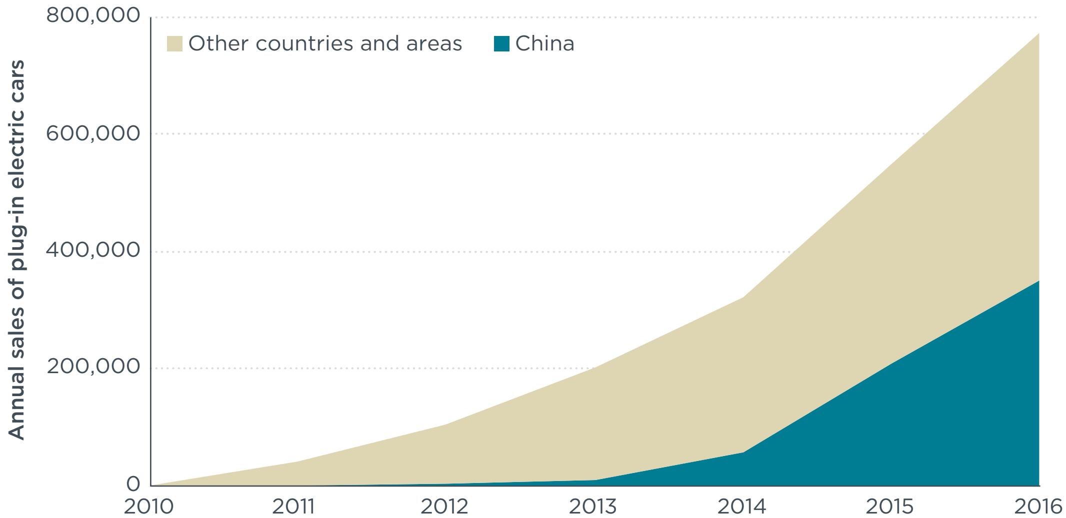

Figure 1. Historical annual sales of plug-in electric passenger vehicles in China, and the rest of the world (2010–2016). Sales and sales share based on European Alternative Fuels Observatory (n.d.); EV Sales (2018); Hybridcars (2018); CAAM (2018).

The fast growth of China's NEV market was partially attributed to a nearly decade-long strong push from its central government. Earlier in this decade, China positioned NEV development as a critical path toward the revitalization of the nation's automotive industry. In 2009, four Chinese central ministries launched a ten-city-thousand-vehicle program, initially targeting 10 pilot cities to each deploy at least a thousand electric-drive vehicles with an overall national target of 10,000 NEVs that year. The major policy behind these goals was a one-time purchase subsidy offered to new, qualified NEVs financed primarily by the central government. Over the years, the program grew significantly in both its scope and the extent of its sophistication. By the end of 2016, the total number of participating pilot cities had increased to 88, almost nine times the original scope of the program. The scope of qualified vehicles also expanded from buses and public, civil service vehicles (e.g., postal and sanitation trucks) to private cars, with each different type of vehicle having to meet its own performance criteria. The multiplied result of the much-expanded scope and extent of the program was a prodigious number of subsidized electric cars.

Despite receiving the same benefits from the central government's policies, these pilot cities presented great variability in their local electric car markets. In 2015, electric car sales in the 88 pilot cities ranged from tens of thousands to nearly none (Figure 2). Figure 2 also clearly shows that only a handful of top subnational markets contributed more than 80% of the entire national electric car sales.

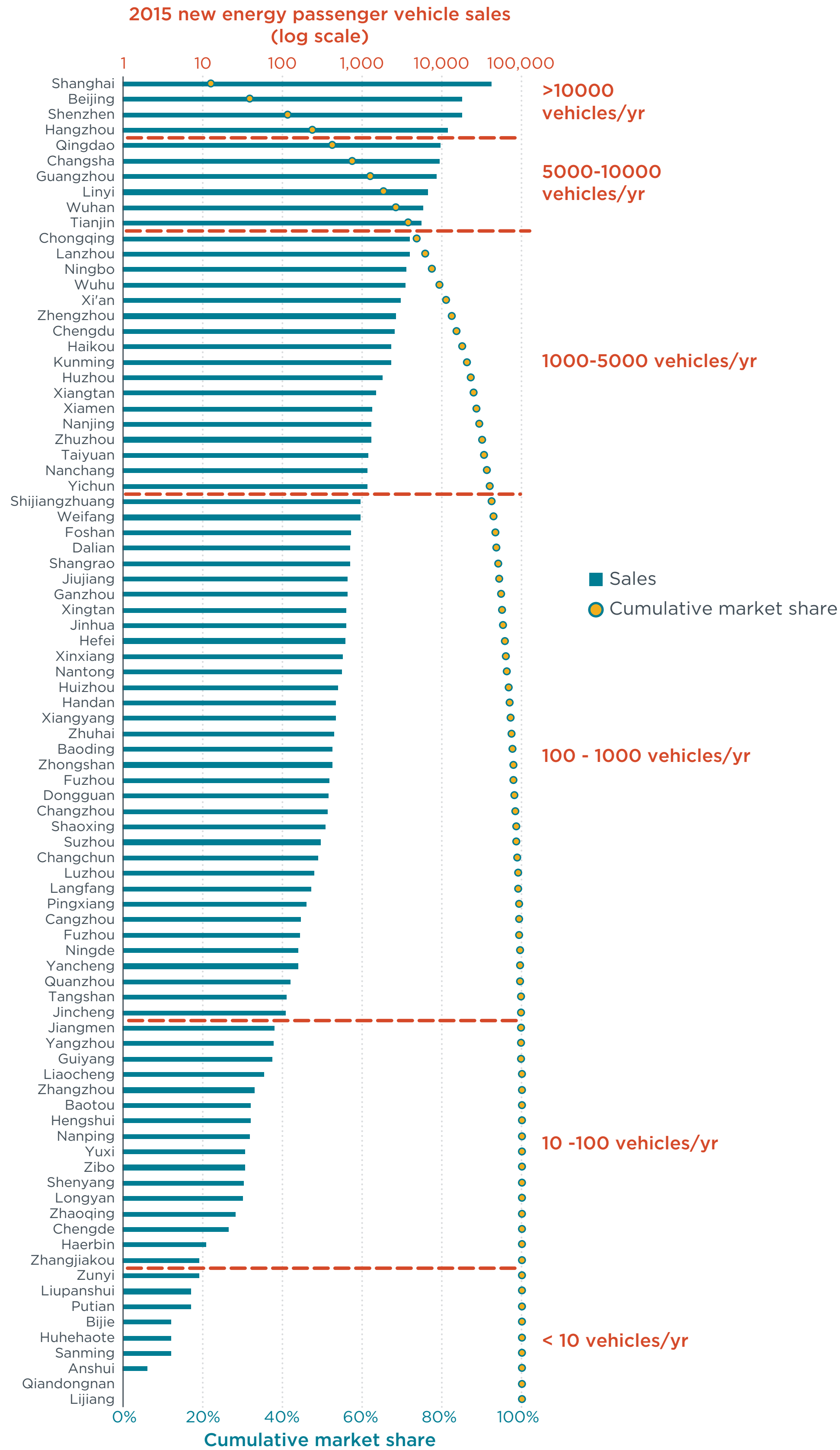

Figure 2. Electric passenger vehicle sales and cumulative market share in pilot cities, 2015.

What has caused these differences? The answers to this critical question not only will uncover the distinct China lessons in vehicle electrification to the rest of the world, but also will help showcase a robust pathway for NEV development to the vast majority of non-pilot cities in China where electric vehicles are largely absent.

This paper intends to answer this question by comprehensively cataloguing governmental actions that were spurring these 30 cities with leading electric car sales and identify the driving forces behind the success of these cities. The study includes detailed qualitative and quantitative analysis over subnational policy actions to promote electric cars and the actual market performance in these 30 cities. In addition, the subnational data also reveals some general patterns of electric car markets in China.

The 30 cities selected for this study were those leading in terms of both absolute electric car sales and market penetration—electric car sales as a percentage of total new passenger vehicle sales, based on 2015 data (Figure 3). These cities collectively represented 84% of the total electric car market in China.

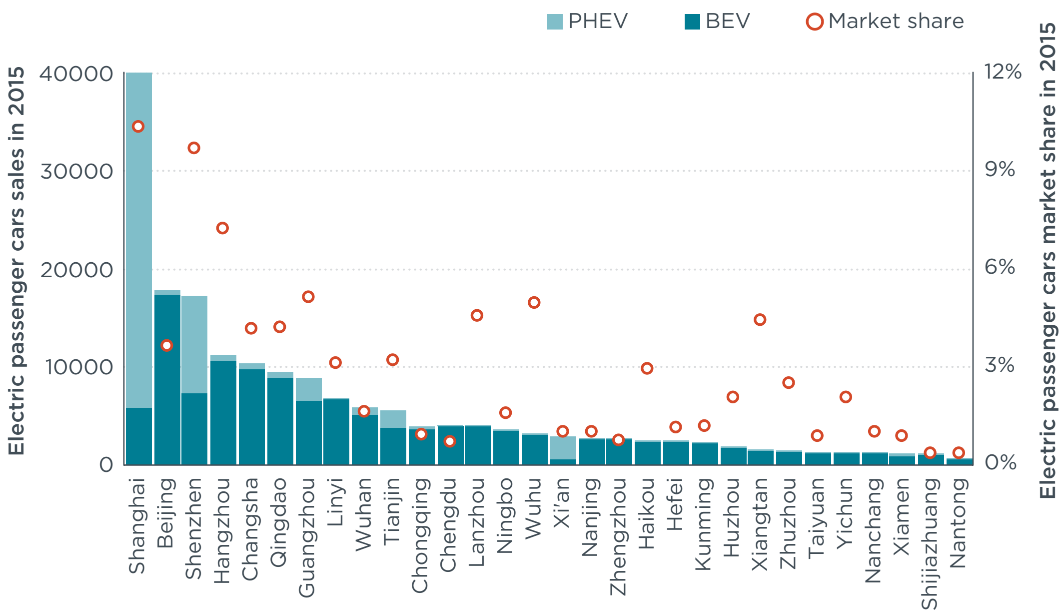

Figure 3. Electric car market size and penetration in the top thirty cities, 2015.

The study relied on five essential datasets obtained or compiled by the International Council on Clean Transportation and its collaborator, China EV100. Data sources are specified in Table 1.

Table 1. Data source

Dataset	Description	Source
A	Aggregate annual passenger car (PC) and electric car registration data of 88 NEV pilot cities in 2015	• Vehicle registration authorities
B	Detailed electric car registration data of top 30 NEV pilot cities in 2015	• Vehicle registration authorities
C	Detailed city-level electric car promotion policies in top 30 NEV pilot cities in 2015	• Local-level public policy documents
D	Charging infrastructure data of top 30 NEV pilot cities in 2015	• Local NEV promotion offices
E	Other data requested of top 30 NEV pilot cities	• Statistical yearbooks (permanent resident population) • National Bureau of Statistics (city area and urban district area) • Baidu Map (gas station numbers) • D1EV app (utility rate and charging service fee)

Note: We intended to collect charging infrastructure data of all the top 30 cities; however, only 14 cities were engaged in the end due to the lack of statistics from the other cities. Besides, we only obtained the stock numbers of charging points, but had no information on their actual usage.

The rest of the paper is organized as follows. Section 2 outlines the distinct characteristics of subnational electric car markets in China. Section 3 catalogs and provides in-depth review of local policy actions in promoting electric cars in the top 30 sub-markets. Methodologies for quantifying consumer benefits of various local incentives are detailed in Section 4, followed by a discussion of the quantification results and findings in Section 5. Section 6 concludes the paper with policy recommendations on how cities can develop a path to sustainable NEV growth.

2 CHARACTERISTICS OF SUBNATIONAL ELECTRIC CAR MARKETS

Before zooming in on the subnational policies and markets, we first focus on some overall trends of local electric car markets in China.

2.1 THE MAJORITY OF ELECTRIC CARS WERE DEPLOYED IN PREDOMINANT CITIES

As indicated in the previous section, a small number of cities have dominated the electric car market in China. The trend is easier to see when we group cities into tiers, an increasingly useful yet unofficial system used to classify Chinese cities concurring with China's accelerated urbanization process. The city tiers are defined based on the overall potential of a city combining elements like size and influence of the economy (absolute GDP, competitiveness, and economic leadership), political status (centrally administrated), population, and other parameters. The thresholds for higher tiers are rather fuzzy, whereas the list of Tier 1 and Tier 2 cities are more widely agreed upon. Tier 1 cities are regional economic or political centers and usually can be described as mega cities in terms of population. They include Beijing, Shanghai, Guangzhou, and Shenzhen as of 2017 ("2017 ranking," 2017). Tier 2 cities are mainly provincial capitals, economically vital cities within a province of which there are currently about 30. The most advanced Tier 2 cities are also called new Tier 1 cities. Many car manufacturers are located in Tier 2 cities.

Tier 1 and 2 cities make up about 14% of the total number of cities in China. In 2015, these cities sold 88% of all the electric cars in China. Figure 4 shows the clear decreasing trend of the number of electric cars sold as the city classes move up. Specifically, Tier 1 cities, on average, sold more than 20,000 electric cars, compared with only a few in Tier 5 cities.

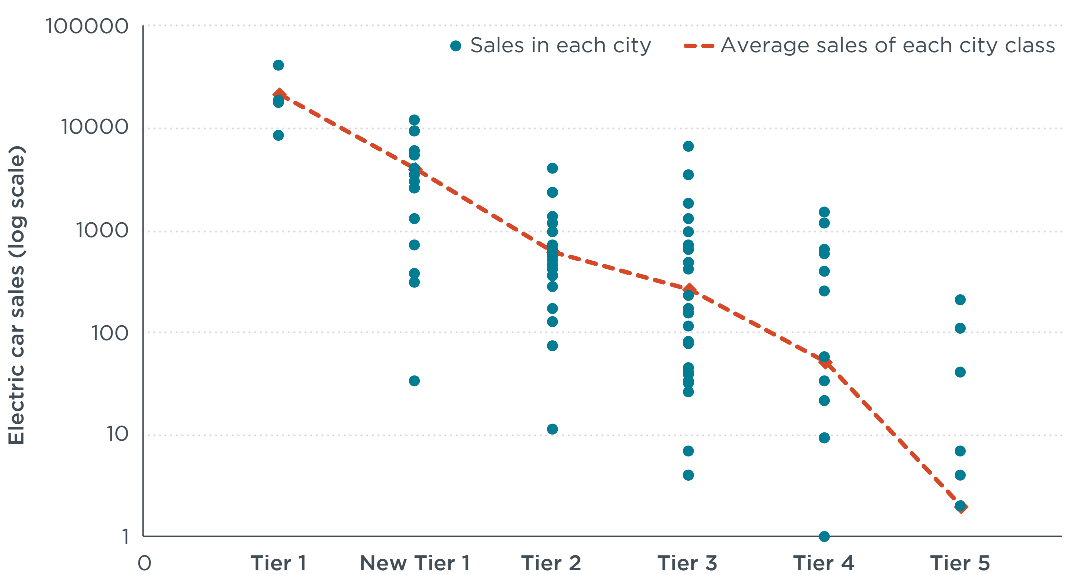

Figure 4. Electric car sales by city class, 2015

2.2 MOST POLLUTED CITIES SAW NO ADVANTAGE IN ELECTRIC CAR DEPLOYMENT

In many of the world's leading electric vehicle markets, reducing air pollution forming pollutants, other pollutants harmful to human health, and greenhouse gas emissions from mobile sources is a primary driver of their aggressive vehicle electrification strategies. For example, California today has nearly half of all zero-emission vehicles in the United States, thanks to its Zero Emission Vehicle mandate which has been in place for more than two decades. The ZEV mandate was initially introduced in the 1990s as a long-term strategy to reduce smog-causing pollutants.

Today, many Chinese cities suffer from severe air pollution. In 2015, among 74 monitored cities, only nine have met the minimum national ambient air quality standard. However, the electric vehicle market in some of the most air-polluted cities is not yet noticeable (Figure 5). Reinforcing what was found in the last sub-section, Figure 5 shows the largest electric car markets were mainly politically high-profile or economically powerful cities. In contrast, Baoding, Xingtai, Hengshui and other cities in the Beijing-Hebei-Tianjin region—the top priority air pollution region in China—had the lowest electric car penetration in 2015.

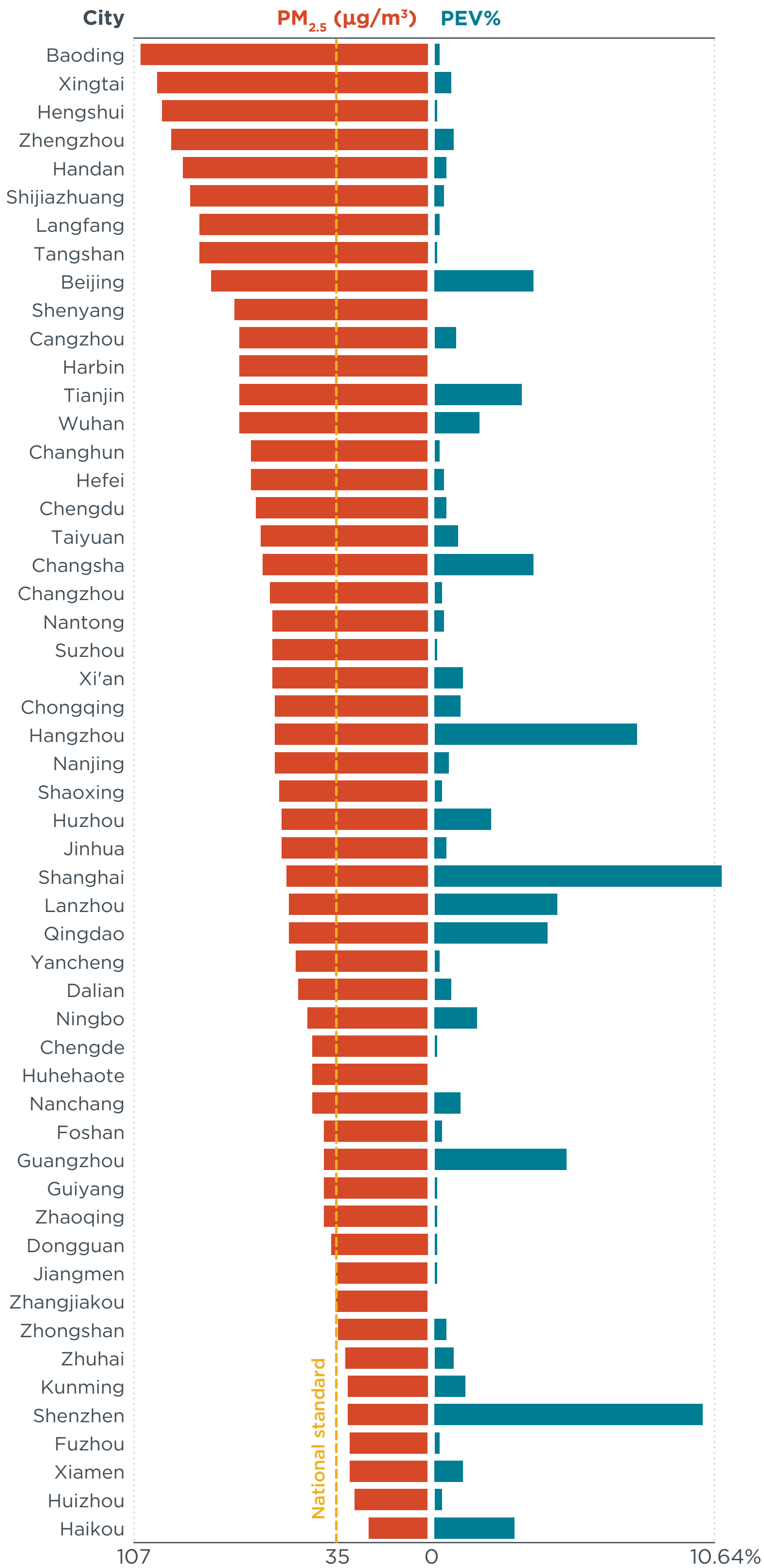

Figure 5. Air quality (PM2.5 concentration) and electric car market share in Chinese cities, 2015.

2.3 BATTERY ELECTRIC TECHNOLOGY DOMINATED THE MAJORITY OF LOCAL MARKETS

This sub-section takes a detailed look into electric vehicle technology options at the local level. In 2015, China's electric car market was made up of battery electric and plug-in hybrid cars only; fuel cell passenger cars had not yet been commercialized. In the top 30 sub-markets we analyzed, 27 were dominated by battery electric vehicles. Only in Shanghai, Shenzhen, and Xi'an did plug-in hybrid car sales exceed the sale of battery electric cars. Shanghai and Shenzhen are the home to major plug-in hybrid electric vehicle (PHEV) manufacturers SAIC Motor and BYD, and BYD recently built a major plant in Xi'an. Overall, two-thirds of the electric cars sold in these 30 cities were battery electric vehicles. Forty-eight battery electric car models were sold, compared with only seven for plug-in hybrid cars. As can be seen from later analysis and discussions, this is partly due to the national strategy and also the differentiated incentives offered from some cities for the two technologies.

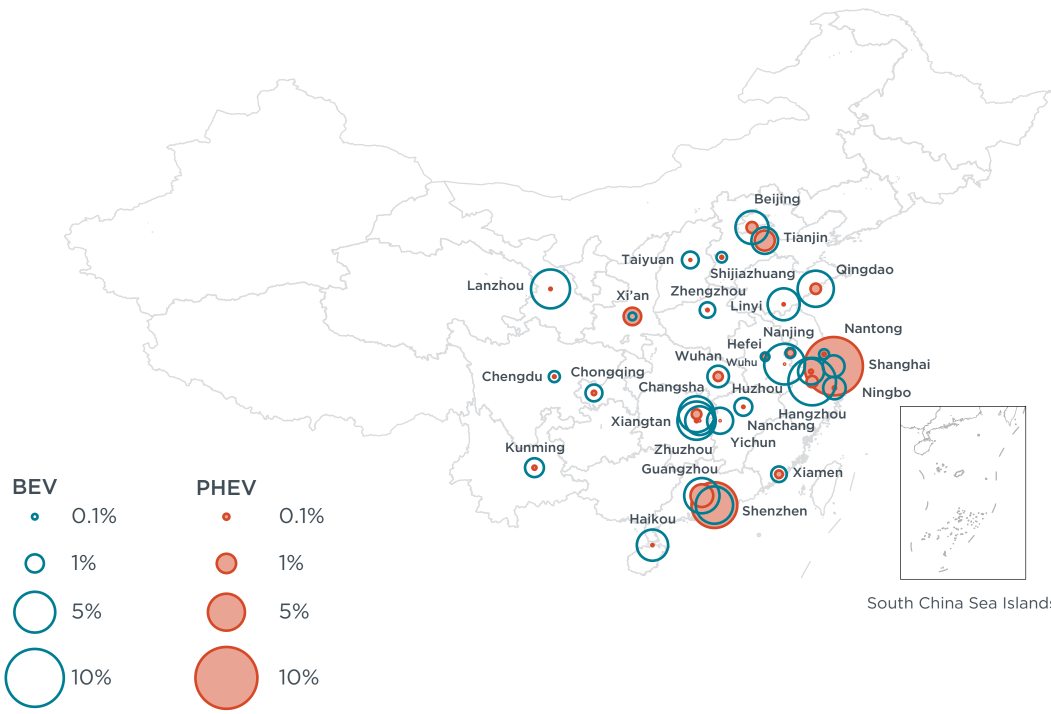

Figure 6. Market penetration of BEV and PHEV by city.

2.4 MICRO BEVS ARE PREFERRED IN MOST CITIES

As Figure 7 illustrates, more than 70% of battery electric cars in the top 30 cities were micro or A00-A0 class cars—two- to four-seaters with typical wheelbase between 2 and 2.3 meters and overall vehicle length under 3.65 meters (European Alternative Fuels Observatory [EAFO], n.d.). These are often economical vehicles with average list price ranging between 30,000 and 60,000 *yuan* ($4,600–$9,200). It is worth mentioning that the manufacturers of top-selling micro BEV models, Zhidou and Kandi, were not among the conventional leading automakers. Small- and medium-sized cars (Class A to B), represent about a quarter of all battery electric cars, followed by three SUV/MPV car models totaling less than 4% of all battery electric cars.

The PHEV segmentation is closer to that of conventional gasoline passenger car market, with six small to medium car models, one SUV model, and no micro cars. The leading car model, the BYD Qin, has taken up more than half of all PHEV sales, followed by the single SUV model BYD Tang, representing 24% of the section.

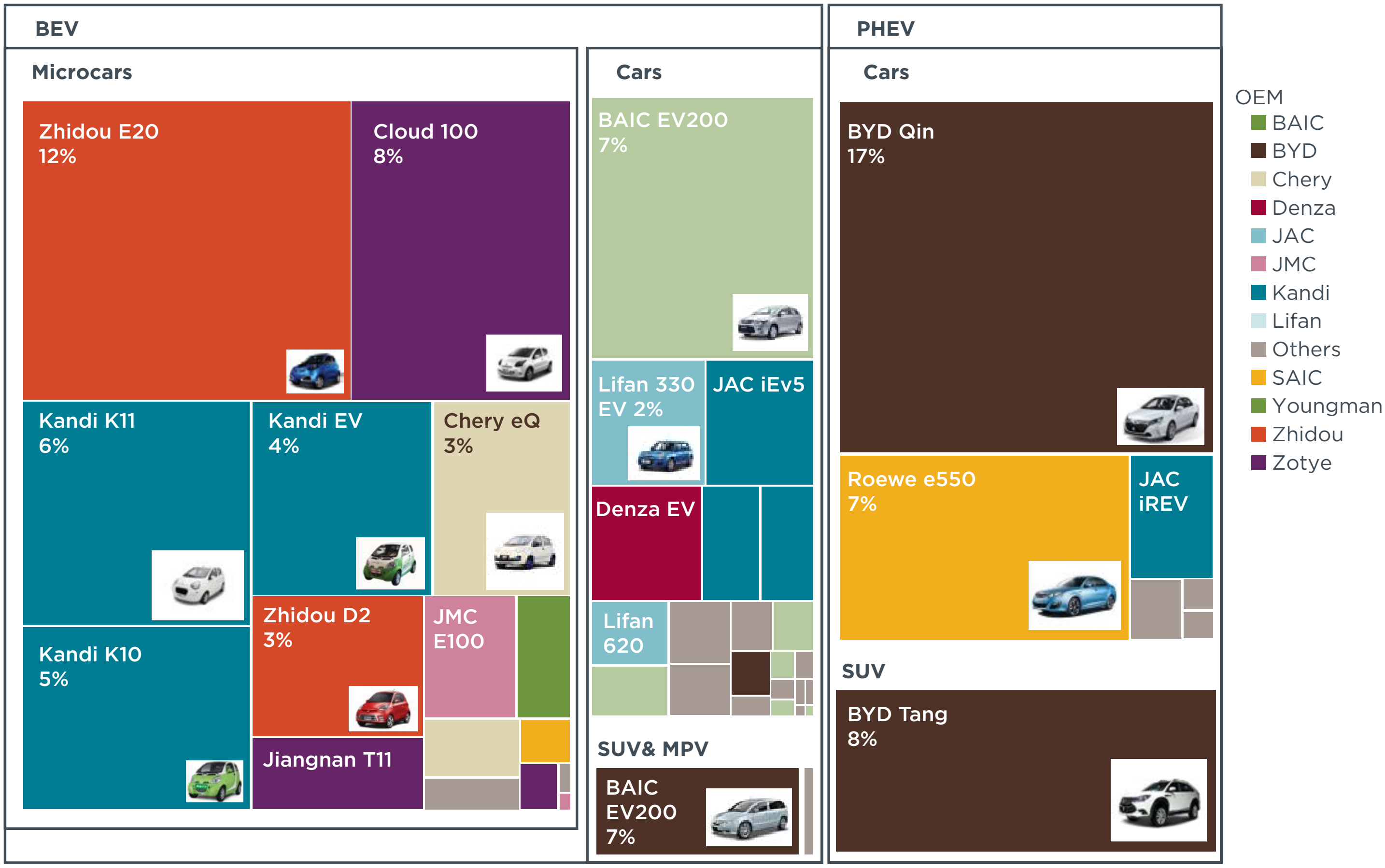

Figure 7. Electric car market share by technology, segment and vehicle model.

Market preference for electric car models at the subnational level varies. In mega cities and a couple of advanced coastal cities, the local consumers prefer mid-priced, small and medium (Class A to B) cars, such as the BYD Qin and BAIC E200, and BYD E5, costing 150,000–250,000 *yuan*. However, the vast majority of the cities in the scope of our study clearly favored cheaper, micro battery electric cars, priced at 100,000–200,000 *yuan*. The Kandi K11—a two-box micro sedan with 2.3-meter wheelbase—was the most popular battery electric car model, topping the electric car sales in six cities, followed by the Cloud 100 and the Zhidou E200, each leading the sales in four cities. The vehicle segment and price features of top-selling models in each city are shown in Figure 8.

Figure 8. Features of top-selling electric car models by city.

2.5 MOST SUBNATIONAL MARKETS WERE DOMINATED BY A SINGLE LOCAL BRAND

In 2015, there were 23 players in China's electric car market, with the eight largest making up more than 90% of the total sales. The leading manufacturers are BYD (27%), Kandi (16%), Zhidou (15%), Zotye (10%), BAIC (8%), SAIC (7%), JAC (5%) and Chery (4%) (Figure 9).

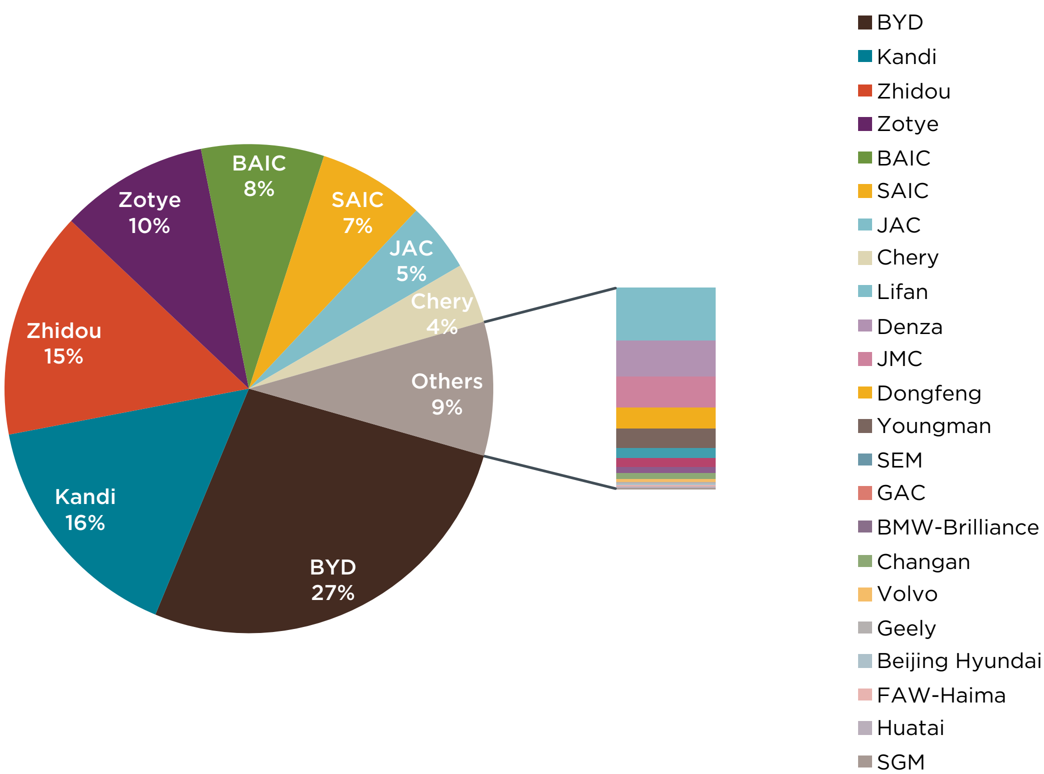

Figure 9. Electric car manufacturer market shares in 2015.

The market performance of these eight brands was quite unequal at the local level. Popular brands in one city can be largely underrepresented in another. In Figure 10, the tinted portion in each city's data bar shows the market share of a specific car brand. Among the 30 cities, 20 were led by one single brand representing more than 50% of the local electric car market. Some of the extreme cases are Kandi, BYD, and Chery models representing 93%, 91%, and more than 99% of the local markets in Huzhou, Xi'an and Wuhu, respectively—nearly monopolies. Further, in 16 cities, the dominant brand either had a major plant or was based in the city. In short, it is quite common in China for local manufacturers to have a definite advantage in selling their electric cars in their home markets.

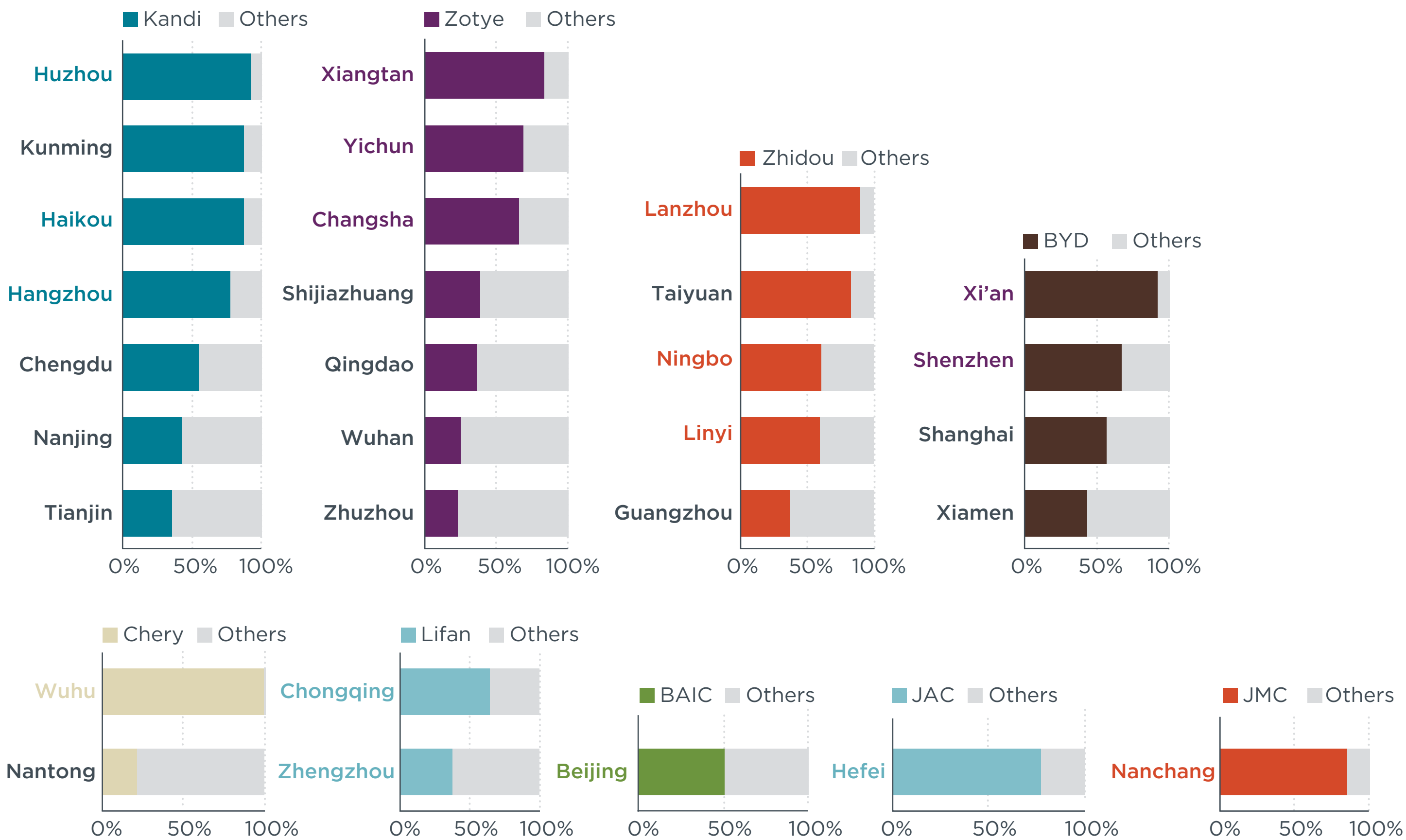

Figure 10. Electric car market share of major brands by city, including home markets for various brands (tinted city names).

3 REVIEW OF NEW ENERGY PASSENGER CAR PROMOTION ACTIONS

This section describes and catalogues actions that are being undertaken to promote electric cars. A wide spectrum of policies has influenced the electric vehicle market in China. Although our study focuses on local-level actions, we first offer a broad context by providing a brief overview of central strategies and policies. At the subnational level, we describe primarily local electric vehicle plans, then incentives targeting individual consumers and fleet owners. The term fleet in this study includes taxis, car-sharing fleets, group purchases, and electric car rental fleets. However, some policies are out of the scope of our study, especially incentives provided to vehicle manufacturers including researcher and development funding, preferential measures for building EV plants, and so on.

3.1 NATIONAL STRATEGY

We emphasize that vehicle electrification currently is a national strategy in China. A series of state leader discourses, macro policy guidance, and central strategies over the past decade have steered the formulation of various central and local policies seen today.

Former President Hu declared in his 2009 congress speech that developing new energy vehicles "conformed with nation's current conditions" ("Promoting new energy vehicles," 2009). In the same year, China's state council proposed the first set of goals for NEV production and deployment and later resulted in the far-reaching ten-city-thousand-vehicle program.

The prominence of new energy vehicles escalated during the succeeding Xi administration. Xi emphasized that developing new energy vehicles is the only way to lead China's auto industry from big to strong. Consequently, China upgraded its strategic plan for the automotive industry with two documents (Ministry of Industry and Information Technology, 2012 and 2015). Both reasserted NEV development as a national strategy and specified the target of having 5 million NEV on the road by 2020 (Energy Storage Application Branch of China Industrial Association of Power Sources, 2017), and its pathway. The development of NEV is not only about reducing emissions, but also promoting the structural adjustment and upgrade of the auto industry and boosting its international competitiveness.

3.2 CENTRAL POLICIES

Although there are many national actions to promote the development and deployment of electric vehicles, we note three primary ones of the most relevance for this study: the fuel efficiency regulation for passenger cars, central subsidies for NEV purchase, and the NEV mandate.

3.2.1. REGULATORY INCENTIVES IN VEHICLE EFFICIENCY STANDARDS

China's progressively tightened efficiency standards for new passenger cars have become a clear driver of its electric car market uptake. The current Phase IV standard sets a fleet-average target of 5 liters per 100 kilometers (L/100km) by 2020, equivalent to about 48 miles per gallon, requiring 28% reduction from the 2015 level or approximately 6% less fuel consumption annually. The 6% annual reduction is among the most ambitious requirements in the world and puts tremendous pressure on manufacturers for compliance. As a compliance flexibility, electric-drive passenger cars were given multipliers toward a manufacturer's corporate standard compliance accounting—one electric car is counted as multiple zero-fuel consumption cars when calculating a company's fleet-average fuel consumption. The multiplier starts with 5 in 2016 and 2017 and begins to phase down to 3 in 2018 and 2019, and further down to 2 in 2020. The Chinese electric vehicle multipliers were also the highest among similar rules in the United States, the EU, and other parts of the world for the equivalent time frame. The motivation for automakers to produce electric cars is due to the considerably relieved compliance burden, provided that these electric cars also benefit from substantial central subsidies (as discussed later in this subsection).

3.2.2. NEV MANDATE

Passed in September 2017, a new energy vehicle mandate took effect in April 2018, requiring conventional passenger car manufacturers to meet 10% and 12% new energy vehicle credit targets in 2019 and 2020, respectively. The rule borrows a similar concept from California's landmark Zero Emission Vehicle program to ensure increased electric (zero emission) vehicle deployment in future years. The NEV target is defined as the ratio between a company's total NEV score and its overall new passenger vehicle production for a given year—that is, the greater a manufacturer's production volume, the more NEV scores it must earn in order to comply. The per vehicle NEV score is a function of the vehicle's technology (BEV, PHEV, or FCV), electric driving range on prescribed testing cycles, energy efficiency, and other utility metrics. For example, the BAIC EV200, a typical battery electric car with a 200km electric range, earns a score of 3.2, compared to a score of 5 for a typical U.S. electric car model, the Bolt, with a 380km electric range. The maximum per vehicle scores for BEV, PHEV, and FCV are 6, 2, and 5, respectively. Manufacturers are given some flexibilities such as credit banking and trading to meet their targets. The actual electric car market penetration in 2020, as a result of this rule, will depend on the technology mix at the time and could end up anywhere between 1% and 12%.

Taken literally, this is a future policy. But during the long process of rule development over the past few years, manufacturers received increasingly clear signals to ramp up their electric vehicle production and get prepared for compliance in the future. This certainly has had implicit impact on the electric car market in recent years.

3.2.3. CENTRAL NEV SUBSIDIES

China began to subsidize new energy vehicles in 2009 to foster the ten-city-thousand-vehicle initiative. Since then, the subsidy program frequently has been fine-tuned to tighten the technical requirements for qualifying vehicles, and also phased down as the technologies are increasingly mature for commercialization (Figure 11).

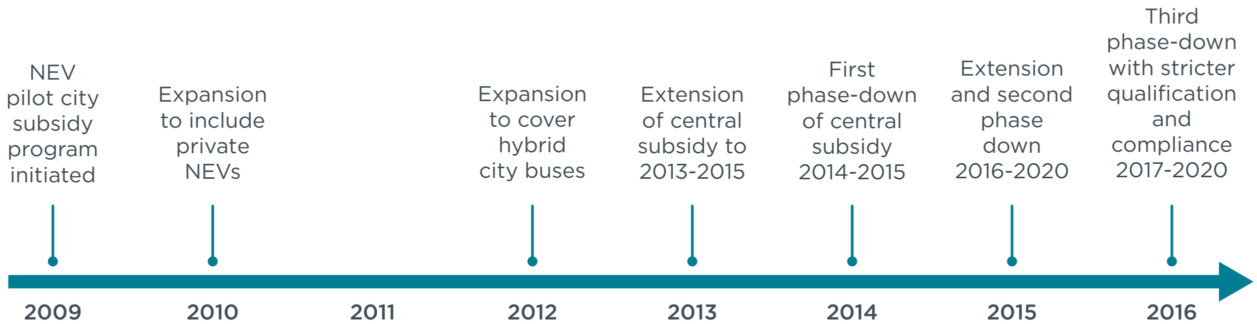

Figure 11. Evolution of China's central subsidy program for NEVs.

As of 2015, battery electric cars with a minimum of 80km electric drive range are eligible for 31,500 to 54,000 *yuan* ($5,000–$8,600) per vehicle, scaled by electric drive range. A typical electric car model of 200km electric range receives 45,000 *yuan*. Plug-in hybrid cars that meet a minimum electric range requirement of 50km receive 31,500 *yuan*. Fuel cell cars are qualified for 180,000 *yuan* of subsidy.

The central subsidies were given to city governments that meet certain requirements, then passed down from the cities to vehicle manufacturers and users. The magnitude of the central subsidies has a direct impact on local subsidies, as many pilot cities provide a matching local subsidy proportionate to the central subsidy. Local subsidies are discussed briefly in the next subsection.

3.2.4. CENTRAL PLANNING AND REQUIREMENTS IN CHARGING INFRASTRUCTURE

To qualify for the central new energy vehicle subsidies, cities must ensure an adequate electric charging infrastructure to support the increasing shift toward an electric vehicle fleet. Despite this general requirement, there was a lack of national guidance for city governments on charging infrastructure development. Furthermore, the planning for the infrastructure is done solely by and with local planning officials and local equipment providers.

The *Guidance for developing electric vehicle charging infrastructure for 2015–2020* released by the National Development and Reform Commission and four other ministries (NDRC et al., 2015) in October 2015 first established clear goals for national and regional electric charging infrastructure layout. According to that document, China will build a national fast-charging network along three vertical (north-south) and three horizontal (east-west) corridors (Figure 12), with an addition of 800 intercity fast-charging stations between 2015 and 2020.

Figure 12. China's planning of a national three-vertical-three-horizontal fast charging network.
Note: extracted from NDRC et al. (2015), Figure 6-2.

The document also identifies three strategic regions with tailored charging infrastructure goals. Beijing, Tianjin, Shanghai, Guangdong, and eight other economically advanced regions and early electric vehicle adopters need to build 7,400 new centralized charging stations, which can have multiple chargers or charging points, and 2.5 million new distributed individual chargers by 2020. The goals for central and northern provinces with NEV pilot cities were 4,300 new charging stations and 2 million new chargers. All remaining provinces were targeting 400 new charging stations and 100,000 new charging points (Figure 13).

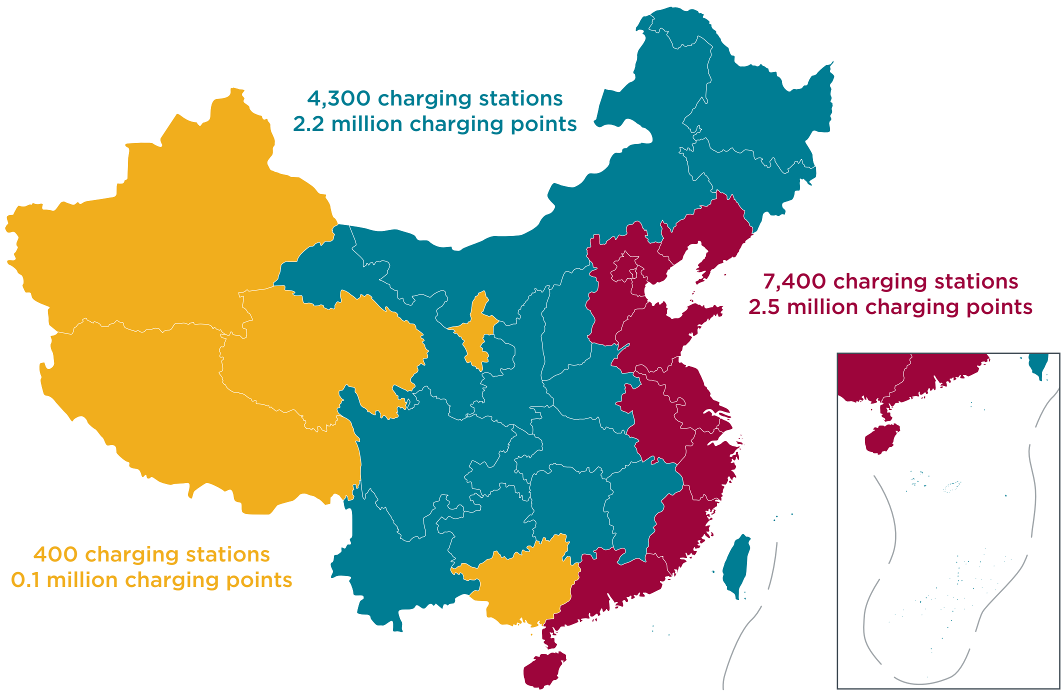

Figure 13. Charging infrastructure planning for three regions by 2020.

Note: Derived from NDRC et al. (2015), Figure 6-3.

Following this document, the Ministry of Finance and four other central agencies developed a set of incentives for charging infrastructure development. Specifically, the central government provides a certain amount of subsidy to cities for building charging equipment, but only after the cities meet a threshold of electric vehicle deployment numbers. In the advanced regions, for example, after a city has deployed 30,000 new energy vehicles, it can receive 9,000 *yuan* per vehicle for charging infrastructure up to a total of 120 million *yuan* (Ministry of Science and Technology, 2016). However, the policy was implemented after 2016 and thus did not play a role in this assessment.

3.2.5. CENTRAL SUPPORT FOR ELECTRIC CAR-SHARING PILOTS

Car-sharing is an emerging business mode for shared mobility in China, in conjunction with the development of electric vehicles. One of China's very first car-sharing programs, EVnet (also called as Chefenxiang) began in 2010 in Hangzhou and has integrated plug-in hybrid car models into its fleet. In July 2014, the particular statement of "exploring various business modes for electric vehicle application including car-sharing" included in a state council report marked China's official support for electric car sharing. Later that year, the Ministry of Science and Technology (MoST) funded four local pilot electric car-sharing programs in Hangzhou, Beijing, Shanghai, and Shenzhen, with 30–50 million *yuan* for each city (Wu, Yang, & Shi, 2015).

3.3 CITY ELECTRIC VEHICLE ACTION PLANS

Echoing the central policy guidance, many pilot cities developed their own electric vehicle strategies and action plans. These local programs often include specific goals in electric vehicle deployment and infrastructure development. They also serve a key role in securing local funding and ensuring collective and coordinated efforts from different government authorities in charge of finance, land use, urban construction, transportation commerce, environmental protection, public safety, and more, in promoting electric vehicles. Table 2 summarizes the specific electric vehicle targets in selected cities.

Table 2. City level electric vehicle deployment targets in 2015

City	NEV deployment target	Infrastructure target
Shenzhen	Total new NEVs: 20,000, including 1,500 buses, 4,000 taxis, 3,500 urban logistics and sanitation trucks, 2,000 commuter and touring coaches, 9,000 in corporation fleet and by private consumers	169 charging stations; 1,978 new fast chargers; 21,750 slow chargers
Shanghai	Total NEVs: 13,000, including 9,500 passenger vehicles, 1,400 buses, and 2,100 urban logistics and sanitation trucks	6,000 AC/DC chargers and 1 hydrogen fueling station
Guangzhou	Total NEVs: 10,000, including 2,000 buses, 1,000 taxis, 2,000 in the public service fleet, 1,000 urban logistics and sanitation trucks, and 4,000 by private consumers	9,970 chargers and 105 charging stations
Wuhu	Total NEVs: 5,110, including 740 in the public service fleet, 1,050 in the corporation fleet, 2,270 by private consumers, 450 taxis, 450 buses, and 150 urban logistics and sanitation trucks	6,000 chargers
Changsha	Total NEVs: 4,500, including 1,100 buses	
Beijing	Total NEV buses should be no less than 4,500; the market share of NEVs in new sanitation trucks should be no less than 50%; the market share of NEVs in new public service fleet should be 100%	10,000 public fast chargers; 3 large charging stations for public transportation; the bus-to-fast charger ratios should be no less than 2:1 for BEVs and 10:1 for PHEVs; for urban taxis, the taxi-to-fast charger ratio should be no less than 3:1; for area taxis, the taxi-to-AC charger ratio and the taxi-to-fast charger ratio should be no less than 1:1 and 5:1
Tianjin	Total NEVs: 8,700, including 2,000 buses, 3,380 postal service trucks, 500 taxis, 120 sanitation trucks, 600 in the public service fleet, and 2,100 by private consumers	1 battery centralized charging station, 21 charging stations for commercial vehicles, 21 charging stations for passenger vehicles, 3 charging stations for sanitation trucks, 6 battery distribution stations, and 1,680 AC chargers
Linyi	Total NEVs: 5,000, including 300 buses, 1,000 taxis, 1,300 commercial logistics trucks, 100 sanitation trucks, 200 in the public service fleet and 2,000 by private consumers	3,240 public AC chargers; 2,000 private AC chargers; 20 public DC chargers; and 6 charging stations
Huzhou	Total NEVs: 600, including 350 urban logistics trucks, 50 buses, 100 taxis, and 100 passenger vehicles	2 charging stations and 100 chargers

City	NEV deployment target	Infrastructure target
Wuhan	Total NEVs: 10,500, including 1,000 buses, 1,000 taxis, 500 in the public service fleet, 300 sanitation trucks, 500 commuter coaches, 1,000 urban logistics trucks, and 6,200 by private consumers	11,640 chargers and 5 charging stations
Ningbo	Total NEVs: 5,000, including 500 buses, 350 taxis, 131 in the public service fleet, 330 urban logistics and sanitation trucks, and 3,689 by private consumers	5,526 AC chargers, 332 charging racks, and 13 charging stations
Kunming	Total NEVs: 3,400, including 1,000 buses, 600 taxis, 200 in the public service fleet, 200 sanitation trucks, and 1,400 by private consumers	3,700 chargers
Xi'an	Total NEVs: 11,000, including 500 buses, 2,000 taxis, 600 in the public service fleet, 200 urban logistics and sanitation trucks, and 7,700 by private consumers	4 charging towers; 42 charging stations; 7,000 chargers and 16 NEV maintenance service network
Nanchang	Total NEVs: 1,300, including 300 buses, 300 taxis, 350 by private consumers, 50 in the public service fleet, 100 postal service trucks, 80 urban logistics trucks, 90 sanitation trucks, and 30 commuter coaches	2 charging stations, 150 DC chargers for public transportation, and 850 AC chargers
Chongqing	Total NEVs: 3,000	5 charging stations, 11 fast chargers, and 275 slow chargers
Xiamen	Total NEVs: 2,480	24 charging stations for buses, 19 charging stations for taxis, 1602 chargers for urban logistics and sanitation trucks, 1,600–2,000 new private chargers, 8–10 new public charging stations, and 1,600–2,000 public chargers by 2020
Taiyuan	Total NEVs: 5,000, including 650 buses, 2,600 taxis, 200 in public service fleet, 320 sanitation trucks, 150 commercial logistics trucks, 60 engineering trucks, 20 touring coaches, and 1,000 by private consumers	5 charging stations for buses and 13 charging stations for passenger vehicles
Zhengzhou	Total NEVs: 8,650, including 3,400 buses, 750 taxis, 4,500 in the public service fleet, sanitation and engineering trucks.	2 large charging stations and 12 small charging stations
Nanjing	Total NEVs: 5,000 (Jiangsu province)	1,487 chargers for buses and 466 chargers for taxis; 170 reserved parking spaces with chargers for government institutions; at least 10 charging stations, 13 switching stations and 200 public chargers
Hefei	Total NEVs: 70,000 by 2017 (Anhui province)	50 charging stations and 35,000 chargers by 2017 (Anhui province)
Shijiazhuang	Total NEVs: 23,000 by 2020, including 3,600 buses, 7,400 urban logistics and sanitation trucks, and 12,000 by private consumers	318 charging stations and 24,150 chargers by 2020
Hangzhou	Total NEVs: 230,000 by 2020 (Zhejiang province); the market share of NEVs in new buses, urban logistics and sanitation trucks should be no less than 30%; the market share of NEVs in new public service fleet should be no less than 50%	800 charging stations and 210,000 chargers by 2020 (Zhejiang province)

3.4 LOCAL CONSUMER INCENTIVES

A wide range of consumer incentives were adopted by cities to stimulate private purchase and use of electric cars. This subsection briefly reviews 10 direct and four indirect incentives and summarizes their applicability for the 30 cities in this study.

Direct incentives are those that offer a direct monetary value to consumers, therefore reducing cost to electric vehicle buyers and owners during vehicle purchase, ownership, and use. The direct incentives that we consider in this study are new vehicle purchase subsidy, annual taxation incentive, parking fee incentive, license plate fee waiver, charging fee reduction, vehicle usage subsidy, vehicle replacement subsidy, car insurance incentive, home charger subsidy, and road toll incentive.

Indirect incentives do not save money for electric car consumer directly, but instead, offer other forms of benefits that have profound impact on daily vehicle operation and are otherwise unavailable to conventional car owners. Such policies in our study are public charger availability, dedicated parking spaces, vehicle registration, and road access privileges.

3.4.1. DIRECT CONSUMER INCENTIVES

Vehicle purchase subsidy. On top of the purchasing support provided by the central government, nearly all cities in this study offer additional financial support to promote electric vehicle purchases. Specifically, 29 cities provided subsidies for the purchase of battery electric cars and 27 cities provided subsidies for the purchase of plug-in electric cars. The per vehicle subsidy in many cities either exactly matches or is certain ratio of the central subsidies, as summarized in Table 3 and Table 4. The amount of subsidy is deducted from the vehicle sales price at purchase.

It is important to understand that not all electric cars qualified for the central subsidy are also eligible for the local subsidy. It is not uncommon that a city requires additional qualification criteria for giving out the local financial incentives. The additional requirements may take many different forms, some technical and others administrative. Nevertheless, they all coincidentally favor local brands, making them look suspiciously like disguised artificial market barriers to non-local competitors.

Beijing and Shanghai maintained their local NEV model catalog and only vehicles listed in the catalog could benefit from local incentives. Their catalogs excluded some models qualified for the central subsidy. In 2015, the BYD Qin was not in Beijing's catalog. The Roewe e550, locally produced and the second highest-selling PHEV model in Shanghai, also was excluded in Beijing.

Hefei lifted the minimum electric range requirement of subsidy to 150km, almost doubling that of the requirement under the central incentive. This unique local requirement coincided with the designed electric range of Hefei's two local electric car models, the J3EV (with 150km e-range) and the J5EV (with 160km–170km e-range), and was high enough to disqualify the national mainstream electric car models, such as the Zhidou E20 and Kandi EV, from the local subsidy program.

Shenzhen subsidized only electric vehicles produced by locally registered manufacturers or their subsidiaries with a minimum authorized capital of 50 million *yuan*.

Table 3. Summary of local subsidies for BEVs

City	Ratio to central subsidy	Range of subsidy (Thousand yuan)
Beijing, Tianjin, Changsha, Chongqing, Xi'an, Wuhan, Ningbo, Huzhou, Xiangtan, Xiamen, Zhuzhou	100% to 2015 subsidy	31.5–54 indexed to electric range
Hefei	100% to 2015 subsidy	45–54 indexed to electric range
Shenzhen, Guangzhou, Qingdao	100% to 2013 subsidy	35–60 indexed to electric range
Linyi, Chengdu, Haikou, Lanzhou	60% to 2015 subsidy	18.9–32.4 indexed to electric range
Kunming, Shijiazhuang	50% to 2015 subsidy	15.75–27 indexed to electric range
Shanghai, Hangzhou, Taiyuan, Yichun	Not relevant	Shanghai: 40 Hangzhou: 30 Taiyuan: 20 Yichun: 30 for central area and 20 for noncentral areas
Wuhu, Nanchang	Not relevant	Wuhu: 8–12 indexed to electric range Nanchang: 25–44 indexed to electric range
Nanjing, Nantong	Not relevant	Nanjing: 15–36 indexed to wheelbase Nantong: 15–35 indexed to wheelbase
Zhengzhou	No local subsidy	0

Table 4. Summary of local subsidies for PHEVs

City	Ratio to central subsidy	Range of subsidy (Thousand yuan)
Tianjin, Changsha, Xi'an, Chongqing, Wuhan, Ningbo, Huzhou, Xiangtan, Xiamen, Zhuzhou	100% to 2015 subsidy	31.5
Shenzhen, Guangzhou, Qingdao	100% to 2013 subsidy	35
Linyi, Chengdu, Haikou, Lanzhou	60% to 2015 subsidy	18.9
Kunming, Shijiazhuang	50% to 2015 subsidy	15.75
Hefei	20% to 2015 subsidy	6.3
Shanghai, Hangzhou	Not relevant	Shanghai: 30 Hangzhou: 20
Wuhu, Nanjing, Nanchang, Nantong, Yichun	Not relevant	Wuhu: 8 Nanjing: 20 Nanchang: 24 Nantong: 20 Yichun: 30 for central area and 20 for noncentral areas
Beijng, Zhengzhou, Taiyuan	No local subsidy	0

Annual vehicle tax incentive. Battery electric cars and qualified plug-in hybrid cars are exempted from the annual Vehicle and Vessel Tax in China. The tax rates are linked to engine size of non-electric cars. Local governments have the authority to determine local tax rates for each car category, based on the allowable ranges provided by the central government. The central guidance on tax rates is provided in Table 5. Electric vehicle owners will save, on average 510 *yuan* ($78) annually and 2,040 *yuan* during four-year ownership of the car, compared with owners of a typical gasoline car (at 1.6L engine size).

Table 5. Vehicle and Vessel tax

Engine size (liter)	Annual tax rate (yuan/vehicle)
≤ 1	60–360
1-1.6	300–540
1.6–2.0	360–660
2.0–2.5	660–1,200
2.5–3.0	1,200–2,400
3.0–4.0	2,400–3,600
>4.0	3,600–5,400

Parking fee incentive. In 2015, six cities—Shenzhen, Yichun, Xi'an, Nanchang, Taiyuan, and Hefei— parking fees were reduced for electric cars to various extents. Two of these cities also provided dedicated parking spaces, which is considered an indirect incentive and therefore will be discussed in the next subsection. Hefei exempted fees for street parking of electric cars in its central urban area. Nanchang halved the parking fee of electric cars for parking on the street or in public lots. Shenzhen offered first-hour free street parking for electric cars.

License plate fee waiver. New vehicle owners typically pay a fee of 125 *yuan* for the cost of license plates. Xi'an, Shijiazhuang and Hefei waived this fee for electric cars.

Charging fee reduction. Electric car owners pay two types of fees when using public chargers which include charging points installed in public charging stations, public parking lots, shopping centers, communities, and public areas in residential neighborhoods: a utility fee for the electricity and a variable charging service fee collected by the charging facility operators. There are more than a dozen major charging facility operators in China, with some of the largest being the State Grid, Potevio, and TGOOD.

A number of cities collaborated with charging operators to provide charging fee incentives. Shenzhen and Shanghai set caps on the charging service fee at 0.45 *yuan*/kWh and 1.6 *yuan*/kWh, respectively. Beijing requires that the charging service fee cannot exceed 15% of the price of #92 gasoline on that day.

Wuhu is among the rare cases to offer free electric car users public charging. The city government fully subsidized the utility fees of all city-financed public charging points.

Home charger subsidy. In 2015, Linyi subsidized 30% of home charger purchase and installation cost up to 3,600 *yuan* per household. Besides city governments, some OEMs provided a free home charger and/or free installation to their users in 2015. For example, BAIC, Chang'an, and JAC provided free home chargers. Consumers of SAIC Roewe electric cars were exempted from both purchase and installation cost of home chargers. Venucia subsidized home charge installation cost up to 10,000 *yuan* per charger ("Installation cost," 2015). The manufacturers' actions are not quantified in the next section.

Vehicle usage subsidy. Two cities in our study, Shenzhen and Xi'an, also provided electric car consumers with a one-time vehicle usage subsidy in addition to the purchase subsidy. Shenzhen provided 10,000–20,000 *yuan* for battery electric cars, depending on vehicle electric drive range, and 10,000 *yuan* for plug-in hybrid cars. Although the policy intention was to encourage the use of electric vehicles, it has no essential requirement for proof of vehicle usage. Xi'an provided 10,000 *yuan* for electric car owners to partially cover the cost of private charger installation and charging.

Vehicle replacement subsidy. Many Chinese cities provided incentives for early retirement of old and high-polluting vehicles. In 2015, Xi'an and Hefei offered additional 3,000 *yuan* subsidies to vehicle owners who replaced their old/dirty cars with electric cars. Wuhu and Taiyuan rewarded conventional car owners who traded in their existing cars and purchased electric cars with 2,000 and 3,000 *yuan*, respectively.

Car insurance incentive. All vehicle owners are subject to paying liability insurance with rates that vary by vehicle category. For a typical car with fewer than six seats, the insurance rate is 950 *yuan* per year. In 2015, Xi'an subsidized the full amount of vehicle liability insurance for private electric car buyers as a policy promoting the purchase of new energy vehicles.

Road toll incentive. In 2015, Shijiazhuang exempted new energy vehicles from paying freeway and other road tolls within its jurisdiction.

3.4.2. INDIRECT CONSUMER INCENTIVES

Public charger availability. Having sufficient range is a key feature for the development of battery electric vehicles. Few of the battery electric vehicles currently available can meet consumers' demands for long-distance travel. Range anxiety is one of the main reasons consumers are hesitant to drive battery electric vehicles. In order to advance the development of new energy vehicles in cities, it is vital to build an extensive, reasonably distributed, and reliable charging infrastructure network to reduce range anxiety and to make driving new energy vehicles more convenient.

In 2015, 18 cities provided subsidies to public charging infrastructure to improve local charging infrastructure networks, including Shenzhen, Hangzhou, Wuhu, Lanzhou, Linyi, Haikou, Huzhou, Yichun, Ningbo, Nanchang, Chongqing, Xiamen, Taiyuan, Nanjing, Shijiazhuang, Hefei, and Nantong. Most cities offered subsidies for a percentage of the cost of the charging stations. For example, Lanzhou subsidized 5% of the total investment in the charging stations; Wuhu subsidized 20%, with the cost of each charging station not exceeding 1 million *yuan*; Shenzhen subsidized 30% of the total infrastructure cost. Nanjing is unique in that its subsidies are not proportional to the cost of the infrastructure, but to its power: 800 *yuan*/kW for AC chargers and 1,200 *yuan*/kW for DC chargers. Linyi also has unique incentives where it subsidized the cost of the land used for charging infrastructure at 50,000 *yuan*/ mu (1 mu ≈ 0.067 hectares).

Dedicated parking space. Sufficient, dedicated parking, especially in congested cities, offers great incentive for consumers to own electric cars. Two local authorities in our study, Xi'an and Yichun, both adopted this measure. Xi'an required that all public parking lots, temporal parking lots, shopping centers, and tourist attractions must have dedicated parking spaces for electric vehicles. In existing major parking lots, at least 5% of parking must be reserved for electric vehicles. That minimum ratio for smaller existing parking lots is 10%. All new parking lots must have 30% dedicated parking spaces for new energy vehicles. Yichun required dedicated parking for electric vehicles in sightseeing areas.

Vehicle registration privilege. Motivated by reducing urban congestion and air pollution, some mega cities imposed an upper limit on new vehicle registrations. For example, Beijing, a city plagued by gridlock, announced a target to keep the number of cars under 6.3 million by 2020 (Government of the city of Beijing, 2018), with progressively lowered caps for new license plates. Such cities usually also have strict restrictions to keep non-local vehicles from traveling in their regions. As a result, to be able to drive a car in such a city, one must obtain local registration. In 2014, seven cities had this measure: Shanghai, Beijing, Guiyang, Guangzhou, Tianjin, Hangzhou, and Shenzhen ("Seven cities implemented," 2014). All of the measures were in effect in 2015 to 2017 as well. The vehicle registration restriction took several forms. In Beijing, new license plates were given out by lottery, compared with by auction in Shanghai. The rest of the cities have implemented something in between.

To create additional appeal to potential electric car buyers, six major cities—all of the previous seven but Guiyang—gave privilege to electric cars in the license plate quota system.

In Shanghai, electric cars were exempted from the license auction that applies to private cars with internal combustion engines. In recent years, the average auction price of new private car licenses climbed sharply, owing to the tightened license quota offered and the strong demand for new cars (Figure 14). In 2015, it cost more than 80,000 *yuan* for a private car buyer to obtain a license plate. This can put the registration fee higher than the cost of the vehicle itself. It is not difficult to imagine that offering a free local license plate was a key factor in Shanghai for consumers deciding whether to purchase electric cars.

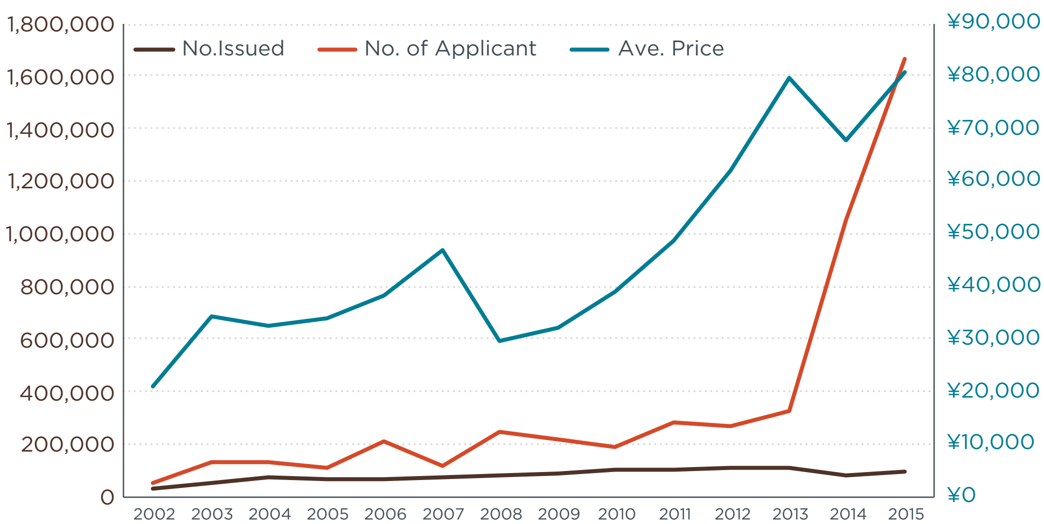

Figure 14. Historical private license plate auction price in Shanghai

Beijing set separate license plate lottery systems for conventional cars and electric cars, with much higher odds to win within the latter. In 2015, Beijing released 120,000 license quotas for conventional cars, cut by about half from the previous year ("Beijing conventional," 2016). The competition for a conventional gasoline-powered car license plate was ferocious—only about one in 200 out of the roughly 3.5 million applicants was granted a license plate. By comparison, the annual quota for private electric cars was set at 20,000, double the amount in the previous year. At year's end, 90% of electric car license applicants had obtained licenses. Especially in the last two lotteries of the year, among a total of six, the electric car licenses were allocated directly—in other words, 100% permitted—to applicants without entering the lottery system (Beijing Municipal Commission of Transport, 2015; "Success rate," 2015). In the following years, Beijing continued to heighten the curbs to the fuel vehicle market while green-lighting that for electric cars ("Beijing passenger car," 2017).

Road access privilege. Similar to the vehicle registration restriction, limiting the number of cars on roads was also adopted by many clogged and polluted cities to tackle congestion and vehicle emissions. When there were serious levels of air pollution, car owners with license plates ending in an even number were permitted to drive on the roads or central areas one day and odd-numbered plates on the next—that is, only half of the private cars were allowed to drive on a given day. On regular (non-pollution) days, private cars were allowed on the roads for four of the five work days.

In six cities in our study—Beijing, Changsha, Lanzhou, Wuhan, Nanchang, and Chengdu—electric cars were made an exception from the vehicle traffic restriction. Electric vehicle owners in these cities enjoyed full road access, at any time, giving them a clear privilege over conventional car owners. Some cities that have recently joined the league of limiting road access for conventional vehicles but not electric vehicles at certain times of the year and day include Shenzhen, Xi'an, Zhengzhou and many other cities. Up until today, more than 29 cities or provinces mentioned giving privileges in road access to new energy vehicles in their electric vehicle development plans, but some of them have yet to materialize this incentive.

3.5 LOCAL FLEET PROGRAMS

Fleet programs target agencies, corporations, communities, and large fleet operators such as taxi companies, instead of individual private consumers. Deployment of electric vehicles in fleets effectively raises public awareness and acceptance of the relatively new technologies and has unique advantages of centralized charging, management, and maintenance. A total of 16 cities in our study had some form of NEV fleet programs: subsidies for new purchase and replacement in taxi fleets (5 cities), car-sharing programs (10 cities), group purchase incentives (5 cities), and subsidies for electric car leasing (1 city). Some cities have adopted multiple programs.

Subsidies for electric taxis. In 2015, Shanghai, Shenzhen, Beijing, Yichun, and Nanchang offered subsidies to local new energy taxis in order to accelerate the development of new energy vehicles in the taxi industry.

Some cities—Beijing, Shanghai, and Nanchang—gave purchase subsidies to new energy taxis. For example, Beijing handed out subsidies to battery electric vehicles based on the difference of the price of a new battery electric taxi and the average price of—according to city transport management agencies—different types of conventional gasoline taxis. If the difference was less than or equal to 50,000 *yuan*, then the subsidy equaled the actual difference; otherwise the subsidy was 50,000 *yuan*. Nanchang had a subsidy of 10,000 *yuan* to 20,000 *yuan* for battery electric taxis based on their range, and a subsidy of 10,000 *yuan* for plug-in hybrid electric taxis if their electric range was greater than 50km.

Other cities—Shenzhen, Yichun, and again Nanchang—provided usage subsidies to new energy taxis. For example, Shenzhen exempted battery electric taxis from usage fees; Nanchang and Yichun reduced the usage fees for all new energy taxis.

Electric car-sharing programs. Many electric car-sharing programs were in partnership with car manufacturers. Ten cities in our study had car-sharing programs in two models: classic car-sharing (similar to that of ZipCar), and Micro Public Transit.

As the initial beneficiary of central support for electric car sharing, Shanghai embarked upon its landmark EVCard program in 2014. The program, largely inspired by ZipCar, is a membership-based, self-service, Internet-technology-integrated car rental system, with its fleet made up solely of electric cars. In 2015, the program was still at the early demonstration stage and involved a single model—the Roewe E520—produced locally by the SAIC group. From 2015 to 2017, the program expanded dramatically and was seen in more than 20 cities with a fleet of 8,400 vehicles consisting of Roewe, Chery, and BMW electric car models.

Hangzhou innovated a variation of car-sharing called Micro Public Transit (*Weigongjiao* in Chinese) in 2013, which also featured a pure electric vehicle fleet. The program allowed users to pick up and drop off vehicles at different stations. Different from the ZipCar type of program, Micro Public Transit is not really self-service. Dedicated staff at each station register each rental car and check vehicle status. Compared with conventional car rental service, the program had far more stations with charging facilities located at urban transportation hotspots and operated with extended hours to complement public transit—and therefore was named Micro Public Transit. There were nearly 10,000 electric cars in the program and more than 50 stations at the end of 2014. Major models in the fleet were the two- and four-seater Kandi K11, produced by a local company, Kandi Technologies.

The other electric car-sharing programs are summarized in Table 6.

Table 6. Local electric car-sharing programs

City	Electric car-sharing program	Operating company	Electric car manufacturer
shanghai	Classic Car-sharing	EVcard	Roewe
Hangzhou	Micro Public Transit	Zhejiang Zuozhongyou Electric Vehicle Service Co., Ltd.	Kandi
Wuhu	Classic Car-sharing	Eakay Car Rental Company	Chery
Lanzhou	Classic Car-sharing	Lanzhou Local Car Rental Company Shengang Car Rental Company	Zhidou, BYD
Xiangtan	Micro Public Transit	Xiangtan Local Car Rental Company	Zhidou
Qingdao	Classic Car-sharing	Qingdao Local Car Rental Company Qingdao Special Call New Energy Co., Ltd.	BAIC, Zotye
Changsha	Micro Public Transit	Hunan Dadi New Energy Vehicle Rental Co., Ltd.	Zotye
Guangzhou	Classic Car-sharing	Dingdong Car Rental Company	Zhidou
Beijing	Classic Car-sharing	Yidu Car Rental Company	BAIC
Linyi	Classic Car-sharing	Linyi Local Car Rental Company	Zhidou

Group purchase incentive. In 2015, Shanghai, Wuhu, Ningbo, Xi'an, and Hefei provided group purchase subsidies to legal entities that made a one-time purchase of more than a certain number of new energy vehicles on top of the regular local purchase subsidies. For example, if a legal entity in Ningbo purchased five or more new energy vehicles, it could obtain a group purchase subsidy of 3,000 *yuan* per vehicle; Xi'an offered a subsidy of 2,000 *yuan* per vehicle, which could then only be used on workplace charging infrastructure, to legal entities that purchased, or organized its employees to purchase, more than 10 new energy vehicles.

Subsidies for electric car rental. In 2015, in order to advance the development of new energy vehicles in the rental car industry, Wuhu subsidized 50% of the rental cost of a new energy vehicle (but no more than 1,000 *yuan* per month per vehicle) based on the rental contract. It also subsidized rental car companies that specialized in new energy vehicle rentals. The subsidy was equal to the sum of the business tax, value-added tax, and enterprise income tax from the rental business.

3.6 POWER BATTERY RECYCLING INCENTIVES

If left untreated, power batteries from new energy vehicles can have a huge impact on the environment. In 2015, Shanghai, Shenzhen, and Hefei published policies that incentivized the recycling of used batteries. In Shanghai, a vehicle manufacturer could get 1,000 *yuan* in subsidies from the city when it recycled batteries from a new energy vehicle; in Shenzhen, the city subsidized new energy passenger vehicle manufacturers or their wholly-owned sales subsidiaries who recycled batteries with 10 *yuan*/kW based on battery capacity; in Hefei, if a battery enterprise carried out battery recycling and echelon use, then the city would subsidize it with 200 *yuan* per electric passenger vehicle and 2,000 *yuan* per electric bus.

3.7 SUMMARY OF LOCAL POLICIES

Table 7 catalogues the actions, described above, that are designed to promote electric cars across the 30 cities of this study. As shown, the implementation of the 20 actions, including those targeting private consumers and fleet owners, varies greatly. One policy, the annual vehicle tax incentive, was uniformly adopted by all cities. Another dominant policy measure, offering public chargers, was deployed in 18 cities. Other major policies were charging fee reduction (seven cities), license plate/registration privilege (six cities), parking fee incentive (six cities), road access privilege (six cities), taxi fleet purchase incentive (five cities), and group purchase subsidy (five cities), respectively. Shenzhen and Xi'an were most aggressive in government efforts of promoting electric cars, in terms of the number of policy actions undertaken.

Table 7. Overview of electric car promotion actions by city

	City-level Actions																				
	Direct Consumer Benefits											Indirect Consumer Benefits				Fleet Program				Other	
Pilot City	BEV Purchase Subsidies	PHEV Purchase Subsidies	Exemption from Vehicle & Vessel Tax	Parking Fee Reductions	License Fee Reductions	Charging Fee Reductions	Usage Subsidies	Trade-in Subsidies	Car Insurance Subsidies	Home Charger Subsidies	Toll Reductions	Public Charger Availability	Reserved Parking Space	License Plate Incentive	Road Access Incentive	Group Purchase Subsidies	Taxi Fleet Subsidies	Car-Sharing Programs	Rental Subsidies	Battery Recycle Subsidies	Total Incentives
Shanghai	X	X	X			X								X		X	X	X		X	9
Shenzhen	X	X	X	X		X	X					X		X			X			X	10
Hangzhou	X	X	X									X		X				X			6
Guangzhou	X	X	X									X		X				X			6
Wuhu	X	X	X			X		X				X				X		X	X		9
Lanzhou	X	X	X									X			X			X			6
Xiangtan	X	X	X															X			4
Qingdao	X	X	X															X			4
Changsha	X	X	X															X			4
Beijing	X		X			X								X	X		X	X			7
Tianjin	X	X	X			X								X	X						6
Linyi	X	X	X							X		X						X			6
Haikou	X	X	X									X									4
Zhuzhou	X	X	X																		3
Huzhou	X	X	X									X									4
Yichun	X	X	X	X								X	X				X				7
Wuhan	X	X	X			X									X						5
Ningbo	X	X	X									X				X					5
Kunming	X	X	X																		3
Xi'an	X	X	X	X	X		X	X	X				X			X					10
Nanchang	X	X	X	X		X						X			X		X				8
Chongqing	X	X	X									X									4
Xiamen	X	X	X									X									4
Taiyuan	X		X	X				X				X									5
Zhengzhou			X																		1
Nanjing	X	X	X									X									4
Chengdu	X	X	X												X						4
Shijiazhuang	X	X	X		X						X	X									6
Hefei	X	X	X	X	X			X				X				X				X	9
Nantong	X	X	X									X									4
Total Cities	29	27	30	6	3	7	2	4	1	1	1	18	2	6	6	5	5	10	1	3	

4 METHODOLOGY FOR QUANTIFYING NEW ENERGY PASSENGER CARS POLICY BENEFITS

We developed a comprehensive evaluation system that quantifies the monetary benefits brought to consumers by the 13 most important and widely used local new energy vehicle incentive policies. These policies include BEV and PHEV purchase subsidies, exemption from vehicle and vessel tax, parking fee reductions, license plate fee reductions, charging fee reductions, one-time usage subsidies, mandatory insurance fee reductions, home charger purchase subsidies, toll reductions, public charging infrastructure subsidies, exemption from licensing restrictions, and exemption from driving restrictions.

Benefits of some of these policies are straightforward to quantify, for example, BEV and PHEV purchase subsidies, while other indirect incentives are more difficult to quantify, for example, exemption from purchase restrictions, exemption from driving restrictions, and public charging infrastructure subsidies. There isn't yet a systematic approach to quantifying these kinds of policies in China. In 2014, we developed a framework to quantify similar incentives in the U.S. EV market, but the vast differences in China and the U.S. markets require some new approaches for China. In this paper, we developed our quantification methodology based on our U.S. research, while taking into consideration China's unique market conditions and policies, for example, the methods to quantify the monetary benefits from exemption from licensing restrictions, exemption from driving restrictions, and public charging infrastructure subsidies.

Many policy benefits vary depending on technology and configuration of the vehicle; therefore, we needed to choose a representative vehicle for each technology. The Zhidou E20 and BYD Qin, the best-selling BEV and PHEV in 2015, are used as the representative vehicles for BEV and PHEV, respectively. In addition, some policies are related to engine capacity, so a counterpart conventional vehicle that is similar to the representative BEV is needed. In this study, we chose the BYD F0 as the counterpart conventional vehicle to the Zhidou E20. Table 8 shows the main specifications for the Zhidou E20, BYD F0, and BYD Qin.

Table 8. Main specifications of the Zhidou E20, BYD F0, and BYD Qin

Specification	Zhidou e20	BYD f0	BYD qin
Type	Microcar	Microcar	Compact
Technology	BEV	Gasoline	PHEV
Curb weight (kg)	670	870	1785
Length (mm)	2765	3460	4740
Engine capacity (L)	NA	1.0	1.5
Fuel consumption (L/100km)	NA	5.1	1.6
Battery capacity (kWh)	10.5	NA	13
Electric range (km)	120	NA	70
Maximum torque (N.m)	NA/82	90/NA	240/250
Maximum power (kW)	NA/18	50/NA	113/110
MSRP (yuan)	108,800	37,900–47,900	209,800–219, 800

Some policies provide upfront benefits, such as purchase subsidies, while others such as vehicle and vessel tax reductions and charging fee reductions, result in annual benefits. In the case of annual benefits, we assume the average length of time a vehicle is retained by the purchaser to be 4 years, and the discount rate to be 4.35%. The benefit is discounted in the years after the first year and summed to give the total benefit over the 4-year period.

Details on the quantification methodology are presented below.

BEV/PHEV purchase subsidies

Because BEV/PHEV local purchase subsidies are upfront, one-time benefits at the time of purchase, the monetary benefits of these subsidies are the subsidies that consumers receive from their local government. One caveat is that 18 of the 30 target cities set an upper limit on the total purchase subsidies (central government subsidies plus local subsidies) a vehicle can receive. If the total subsidies of a vehicle exceed this limit, then we need to recalculate the actual subsidies it can receive. Specifically, the subsidy that a vehicle can actually receive from the local government is calculated as the limit set by the city minus the subsidy from the central government. For example, in 2015, our representative BEV, the Zhidou E20, can receive 31,500 *yuan* in subsidies from the central government, and in Shanghai, 40,000 *yuan* from the local government. The total possible subsidies would be 31,500 + 40,000 = 71,500 *yuan*, but that exceeds the upper limit set by Shanghai of 50% of the vehicle price—in this case 108,800 *yuan*—so the subsidy is limited to 54,400 *yuan*/vehicle. Therefore, the actual subsidy a Zhidou E20 receives from Shanghai comes to 54,400 - 31,500 = 22,900 *yuan*, which is the monetary benefit that this policy brings to BEV consumers in Shanghai.

Exemption from vehicle and vessel tax

For a PHEV, car owners would have to pay the vehicle and vessel tax based on engine capacity if not for this exemption. Take the representative PHEV, the BYD Qin, as an example. The tax based on its 1.5L engine capacity is 180 *yuan*/vehicle/year, which already considers the reduction in tax by half for passenger cars with an engine capacity less than 1.6L; tax rates vary by city. Because of this exemption, PHEV car owners get the monetary benefit of 180 *yuan*/year by not having to pay this tax. Using the average length of time a new vehicle is retained by the purchaser and the discount rate, the total monetary benefit is 180 x [1 + (1+4.35%)^(-1) + (1+4.35%)^(-2) + (1+4.35%)^(-3)] - 0 = 676 *yuan*. Monetary benefits vary by city and range from 564 to 789 *yuan*.

The calculation for BEVs is a bit different. Because BEVs do not have engine capacity, we can’t apply the same method to BEVs. Instead, we use its counterpart conventional vehicle, the BYD F0 with 1.0L engine capacity, and apply the same methods as used with the PHEV to calculate the monetary benefits for a BEV owner. For a BEV owner in Shanghai, the tax in the first year is 90 *yuan*, which already considers the reduction in tax by half for passenger cars with an engine capacity less than 1.6L; tax rates vary by city. Using the 4.35% discount rate, the total monetary benefit is 90 x [1 + (1+4.35%)^(-1) + (1+4.35%)^(-2) + (1+4.35%)^(-3)] - 0 = 338 *yuan*. Monetary benefits vary by city and range from 113 to 507 *yuan*.

Parking fee reductions

The following equation is used to calculate the monetary benefits of parking fee reductions for new energy vehicle buyers and owners in a single year:

$$AB = [261 \times \min(RH, H_{wk}) \times RR \times SD] + [104 \times \min(RH, H_{wkd}) \times RR]$$

AB: annual benefit
RH: reduced-rate parking hours per day
H_{wk}: typical parking hours during weekdays
H_{wkd}: typical parking hours during weekends
RR: reduced rate
SD: share of vehicle owners who drive to work

The first part of this equation calculates the parking fee reductions in the 261 working days in a year, and the second part calculates that in the 104 weekend days.

In this study, we assume that the parking duration is 8 hours for a regular weekday, and 1 hour for a regular weekend. Because some cities (e.g., Shenzhen, Xi'an) only reduce the fee for the first 1–2 hours, and some cities allow free parking for as long as the vehicle is parked (e.g., Hefei), we use the minimum of the allowed reduced-rate parking hours and typical parking hours during weekdays to represent the actual hours that a car owner is able to receive this benefit. In addition, some car owners don't drive to work, and therefore can't be included when calculating the average monetary benefit for a car owner. We use the share of vehicle owners who drive to work to take this into consideration. In this study, we assume 20%[1] of car owners drive to work. Typical parking rates in each city are based on online research.

The equation above calculates the monetary benefits in the first year. This benefit is discounted in the years after the first year and summed to give the total benefit over the 4-year period of vehicle ownership.

License plate fee reductions

In 2015, the cities of Xi'an, Hefei, and Shijiazhuang offered license plate fee reductions for new energy vehicle buyers. The monetary benefit of this policy is the production cost of the license plate, 125 *yuan*.

Charging fee reductions

We use the equation below to calculate the monetary benefits of charging fee reductions for new energy vehicle buyers and owners in a single year.

$$AB = [(SF_{w/o} - SF_{w/})] \times EC \times DS \times 365] \times (1 - SC)$$

AB: annual benefit
$SF_{w/o}$: service fee without this policy
$SF_{w/}$: service fee with this policy
EC: electricity consumption
DS: typical daily driving distance
SC: share of vehicle owners with a home charger

1 This does not include vehicle owners who drive to work but do not pay for parking, for example where free parking is provided by employers.

The actual service fee in cities is obtained from survey and research, using the average service fee from the main public charging infrastructure provider in each of the cites. Because we have little reference as to how much the fee would be without these incentives, we took Shanghai's average charging service fee with the incentive (0.82 *yuan*/kWh) and the maximum service fee under the policy (1.6 *yuan*/kWh), and calculated the average (1.21 *yuan*/kWh) as the rate without the policy. The reason we chose Shanghai is that the service fee cap is relatively high at 1.6 *yuan*/kWh, and the actual average service fee is only 0.82 *yuan*/kWh. If the limit is lifted, it's likely that the service fee will increase, but not quite reaching the cap. Because the main public charging infrastructure providers are similar in major metropolitan areas, we applied the same rate (1.21 *yuan*/kWh) to Beijing and Shenzhen as the service fee without the policy. For the other four cities that provide this policy (Tianjin, Wuhan, Nanchang, and Wuhu), we used the average service fee in Hangzhou (0.72 *yuan*/kWh), which doesn't have this policy, to approximate the fees in these cities in a scenario where they don't have this incentive. The annual driving distance is derived from the average daily driving range (39km/day) from a survey conducted in Beijing (Zhang & Wang, 2014) and applies to all cities.

We assume that electric vehicle owners who don't have a home charger would use public charging stations and thus benefit from this policy, while the ones who have a home charger would not. We estimate the percentage of electric vehicle owners who have a home charger by dividing the total number of new home chargers installed by the total sales in 2014 and 2015 combined.

The equation above calculates the monetary benefits in the first year. This benefit is discounted in the years after the first year and summed to give the total benefit over the 4-year period of vehicle ownership.

One-time usage subsidies

Shenzhen and Xi'an provided one-time usage subsidies to new energy vehicle owners in 2015. The amount of the monetary benefit was the amount of the subsidies. The Zhidou E20, our representative BEV, and the BYD Qin, our representative PHEV, received 10,000 *yuan*/vehicle in one-time usage subsidies in these two cities.

Mandatory insurance fee reductions

Only Xi'an had this policy in place in 2015, and the reductions only applied the first time the insurance fee was paid. Thus, the monetary benefit of this policy was the mandatory insurance fee in the first year, which is 950 *yuan*.

Home charger purchase subsidies

Only Linyi provided home charger purchase subsidies in 2015, with a maximum of 3600 *yuan*/charger. We assume that the new energy vehicle buyers in Linyi all took advantage of this policy and installed home chargers. Thus, the monetary benefit of this policy is the value of the subsidies, which is 3600 *yuan*.

Toll reductions

Of the 30 cities analyzed, only Shijiazhuang had this policy. We use the equation below to calculate the monetary benefits of charging fee reductions for new energy vehicle buyers and owners in a single year.

$AB = (DS \times 365 \times ST \times AF_{city} \times AF_{hw}) \times TR$

AB: annual benefit
DS: typical daily driving distance
ST: share of toll roads
AF_{city}: adjustment factor (city road)
AF_{hw}: adjustment factor (highway)
TR: typical toll rate

The calculation within the brackets is the total distance that a vehicle travels on toll roads. The annual driving distance is derived from the average daily driving range (39km/day) from a survey conducted in Beijing (Zhang & Wang, 2014). The percentage of toll roads is the ratio of toll roads to all roads at the national level, which was 3.6% in 2015 (Ministry of Transport, 2017). Because most of the distance an average person travels is in the city where the roads are mostly free, we apply a 50% adjustment factor (city road) in the equation to adjust for this effect in this analysis. The percentage of highway toll roads was 71.2% in 2015 (Ministry of Transport, 2017), but we assume that people frequently do not drive their BEVs on highways due to range anxiety. We use the adjustment factor (highway) to better estimate the distance that BEV owners travel on toll roads. The adjustment factor (highway) is 1 – 71.2% = 28.8%. We used the median toll rate—0.4 *yuan* per car kilometer—traveled over the dozens of toll roads in Shijiazhuang, with rates ranging from 0.3 to 0.5 *yuan* per car kilometer, to approximate the typical toll rate in this study.

The equation above calculates the monetary benefits in the first year. This benefit is discounted in the years after the first year and summed to give the total benefit over the 4-year period of vehicle ownership.

Public charging infrastructure subsidies

Under ideal conditions where there are sufficient chargers so that drivers do not need to worry about range, people can drive electric vehicles for even long-distance trips. However, the current situation is far from this ideal condition, and new energy car drivers may not have the confidence to drive a long-distance trip that exceeds the electric range, considering that there are not a sufficient number of charging stations along the way. The benefit of not having range anxiety (i.e., under the ideal charging condition) is that it eliminates the need to rent a substitute vehicle on days when trips exceed the electric range.

The benefit of chargers that are publicly available to consumers is in providing range confidence. The better coverage of charging stations a city provides, the less likely that an electric vehicle owner needs to rent a substitute vehicle for his/her daily travel, thus reducing the extra cost of renting. The extra rental cost can be seen as the monetary benefit of the public charging infrastructure subsidies that a city provides. The value of increased range confidence from increased electric charger availability is approximated for BEVs but not for PHEVs. Because PHEVs can refuel at conventional gasoline stations, we assume that PHEV drivers do not experience range anxiety.

We use the equation below to calculate the monetary benefits of public charging infrastructure subsidies for new energy vehicle buyers and owners in a single year,

$AB = AD \times CR \times (PC_{real}/PC_{ideal}) \times SC$

AB: annual benefit
AD: typical annual number of days with insufficient BEV range
CR: cost of rental car
PC_{real}: real number of public chargers
$PC_{sufficient}$: sufficient number of public charger
SC: share of city-funded public chargers

The benefit for the median driver under ideal charger availability is adjusted from a study that calculated days of insufficient range of EVs based on drivers' daily travel distance distributions from National Household Travel Survey 2001 data (Lin & Greene, 2011). The penalty for insufficient range is that drivers would need to rent a car to cover the trips on these days. According to the survey, for a median driver who ranks 50% in annual miles traveled in the survey, the number of days with insufficient BEV range is approximately 30 days with a 160km (100-mile) BEV, 6 days with a 240km (150-mile) BEV, and 4 days with a 320km (200-mile) BEV. So, for the Zhidou E20, a BEV with a 120km (75-mile) range, the number of days with insufficient BEV range is about 22.5. Although we use this number as a ballpark figure, we recognize that other factors can affect this estimate, for example, different driving patterns in China, possible public transportation routes, and having another gasoline car in the household, which can result in the increase or decrease of the benefit.

The cost of a rental car varies across cities, car types, and when and where people rent the car. We used 300 *yuan*/day, including insurance, to approximate the average of these conditions ("How much does it cost", 2013).

Multiplying the rental cost per day and the number of days with insufficient BEV range yields the monetary benefit under the ideal condition, which means that there are sufficient chargers so that drivers do not need to worry about range and don't need a substitute vehicle. But the current condition is far from sufficient, so we use the percentage to this sufficient level of station coverage (value in sufficient condition is 1) to take this into account. This factor is calculated by dividing the current total number of chargers by the number that provides sufficient level of station coverage in each city. The sufficient level of station coverage in a city is based on the population density and urban district area (Melaina & Bremson, 2008). The actual number of stations is obtained by phone calls to local authorities, surveys, and online research. Because we don't have the number of level 2 or fast chargers for some of the cities, the average of this factor in Hangzhou and Nanjing (16.9%) is used as a typical value for the capital cities of a province, and the value of Huzhou (1.5%) is used for other non-capital, smaller cities.

The calculation above yields the total monetary benefits from all public charging stations. The benefits provided by the city government are related to the number of public chargers for which the city provides funding. Therefore, we need to multiply by the percentage of public charging stations funded by the city to isolate the effect of city policies. Most cities cover a certain percentage of the infrastructure cost, in which case we simply use this percentage value. In a few cities where a lump sum is provided, or where the subsidies are based on per kW of power or per area of land use, the value of the subsidies is translated into a percentage of the total infrastructure cost based on factors such as typical charger cost and power of outlet.

The equation above calculates the monetary benefits in the first year. This benefit is discounted in the years after the first year and summed to give the total benefit over the 4-year period of vehicle ownership.

Exemption from licensing restrictions

In the six cities where there are licensing restrictions, consumers need to pay a certain cost for a conventional vehicle plate, whether it is acquired by auction, by lottery, or a combination of both. In other words, a conventional vehicle plate has value in these cities in terms of a vehicle buyer's money or time, which is to say the need to wait for the next lottery in case of losing it this time. New energy vehicles enjoy exemption from such licensing restrictions in these cities, so we assume that there is no cost to acquire a license plate. Therefore, the monetary benefit of this policy is the value of a conventional vehicle license plate.

As shown in Table 9, we used the average auction price as the value of a conventional vehicle license plate for cities with an auction mechanism, and the difference in the price of a used vehicle with and without a license plate in Beijing,[2] where the only mechanism is lottery, as the value of a conventional vehicle license plate in the case of a lottery option. The value of a Beijing conventional vehicle license plate is the highest, at 130,000 *yuan* ("A Beijing license plate," 2011), and it also exceeds 80,000 *yuan* in Shanghai, whereas the value in the rest of the cities ranges from 20,000–30,000 *yuan*. The higher value in Beijing compared to Shanghai is likely due to a combination of supply and demand and/or the added value of the time and effort required to acquire the license plate. Compared to other policies, this policy can provide very high monetary benefits to new energy car owners.

Table 9. Monetary benefits provided by the exemption from purchase restrictions for new energy vehicles in 2015 in the six cities

City	Mechanism	Benefits
Shanghai	Auction	Average auction price in 2015 (80,686 *yuan*/vehicle)
Beijing	Lottery	Difference in the price of a used vehicle with and without a license place (130,000 *yuan*/vehicle)
Shenzhen	Auction + lottery	Average auction price in 2015 (26,715 *yuan*/vehicle)
Guangzhou	Auction + lottery	Average auction price in 2015 (22,165 *yuan*/vehicle)
Tianjin	Auction + lottery	Average auction price in 2015 (20,749 *yuan*/vehicle)
Hangzhou	Auction + lottery	Average auction price in 2015 (24,841 *yuan*/vehicle)

2 According to an announcement from the Trade and Industry Bureau and the Transportation Commission, from April 1, 2011, a fleet of 12,000 documented used vehicles can be sold with a license plates. Currently, used vehicles cannot be sold with license plates. More details at http://news.cntv.cn/20110412/110430_1.shtml

Exemption from driving restrictions

On days when a vehicle owner's personal vehicle is restricted from the road, he/she must have alternatives to meet essential daily travel needs, such as getting to work, either by public transportation or taxis, which incur additional costs. Such additional costs are the monetary benefits provided by the exemption from driving restrictions for new energy vehicles.

We use the equation below to calculate the monetary benefits of the exemption from driving restrictions for new energy vehicle buyers and owners in a single year.

$$AB = [(S_{taxi} \times C_{taxi}) + (S_{pub} \times C_{pub})] \times AD \times SD$$

AB: annual benefit
S_{taxi}: share of vehicle owners who choose taxis on days with driving restrictions
C_{taxi}: typical cost of taking a taxi
S_{pub}: share of vehicle owners who choose public transportation at days with driving restrictions
C_{pub}: typical cost of taking public transportation
AD: annual days with driving restrictions
SD: share of vehicle owners who drive to work

The calculation within the brackets shows the extra cost for a vehicle owner on a day when a personal vehicle is restricted. Multiplying by the total days with driving restrictions in a year yields the total annual extra cost. We assume the possibility that a vehicle owner takes a taxi or public transportation is 50%, that the one-way fare of public transportation is 4 *yuan*, and that the one-way cost of a taxi is 30 *yuan*. Both conventional driving restrictions (e.g., based on last digit of license plate or odd/even license plate number) and nonconventional restrictions, such as on days of high pollution events, are taken into account when calculating the annual days with driving restrictions.

Some car owners don't drive to work, and because most of the restricted days fall on weekdays, and we consider other possible errands such as shopping as flexible, we assume that these car owners don't enjoy the benefit brought by this policy and are not included when calculating the average monetary benefits. We used the share of vehicle owners who drive to work to take this into consideration. In this study, we assume 20% of vehicle owners drive to work. This does not include vehicle owners who drive to work but do not pay for parking, for example, where free parking is provided by their employers.

The equation above calculates the monetary benefits in the first year. This benefit is discounted in the years after the first year and summed to give the total benefit over the 4-year period of vehicle ownership.

5 COMPARISON AND DISCUSSION

This section compares quantification results of various policy impacts in dollar amounts among 30 studied cities and analyzes the data from different angles to explore potential links between the local passenger electric car (PEC) market uptake and various stimulating policies and actions. Following the same policy action categorization as in the previous section, we first discuss the impact of private consumer-targeted incentives, then that of electric car fleet programs. A semi-qualitative rating of all policy measures and a comparison against electric car market size of the 30 cities is provided at the end of this section.

5.1 IMPACT OF CONSUMER INCENTIVES

Table 10 and Table 11 pooled the quantified monetary values of all each policy actions for battery electric cars and plug-in hybrid electric cars, respectively, evaluated in Section 5. Figures 15 and 16 compared monetized consumer benefits and market shares for each electric car technology, respectively, in 30 cities. In both figures, each data bar represented a city, and shaded fractions within each bar tallied the consumer benefits in dollar amounts for various policies. Market shares of each type of electric car were denoted as dots overlaying the bars and corresponding to the percentages on the right axis.

Table 10. Monetary values of PHEV incentives for private consumers (in 1,000 *yuan*)

City	Purchase Subsidy	Annual Tax Incentive	Usage Subsidy	License Fee Waiver	Charging Fee Incentive	Parking Fee Incentive	Home Charger Subsidy	Car Insurance Incentive	Road Toll Incentive	Registration Incentive	Road Access Incentive	Subtotal
Shanghai	30.0	0.7	0.0	0.0	2.4	0.0	0.0	0.0	0.0	80.7	0.0	113.9
Shenzhen	35.0	0.7	10.0	0.0	0.5	2.9	0.0	0.0	0.0	26.7	0.0	75.8
Guangzhou	35.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.2	0.0	57.8
Tianjin	31.5	0.7	0.0	0.0	0.3	0.0	0.0	0.0	0.0	20.7	0.0	53.3
Xi'an	31.5	0.6	10.0	0.1	0.0	2.9	0.0	1.0	0.0	0.0	0.0	46.1
Hangzhou	20.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.8	0.0	45.4
Wuhan	31.5	0.7	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	4.6	39.0
Qingdao	35.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.7
Xiamen	31.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.1
Ningbo	31.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.1
Zhuzhou	31.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.1
Huzhou	31.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.1
Xiangtan	31.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.1
Chongqing	31.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.1
Changsha	31.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.1
Nanchang	24.0	0.6	0.0	0.0	0.3	2.4	0.0	0.0	0.0	0.0	1.3	28.6
Linyi	18.9	0.7	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	23.2
Nanjing	20.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.6
Nantong	20.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.6
Lanzhou	18.9	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	19.9
Chengdu	18.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	19.8
Haikou	18.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.5
Shijiazhuang	15.8	0.6	0.0	0.1	0.0	0.0	0.0	0.0	0.4	0.0	0.1	17.0
Kunming	15.8	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.3
Hefei	6.3	0.6	0.0	0.1	0.0	5.1	0.0	0.0	0.0	0.0	0.0	12.1
Wuhu	8.0	0.6	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	8.8
Yichun	0.0	0.7	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	3.3
Taiyuan	0.0	0.6	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	3.0
Beijing	0.0	0.7	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	2.8
Zhengzhou	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6

Table 11. Monetary values of BEV incentives for private consumers (in 1,000 *yuan*)

City	Purchase Subsidy	Annual Tax Incentive	Usage Subsidy	License Fee Waiver	Charging Fee Incentive	Parking Fee Incentive	Home Charger Subsidy	Car Insurance Incentive	Road Toll Incentive	Public Charging Offering	Registration Incentive	Road Access Incentive	Subtotal
Shanghai	22.9	0.3	0.1	0.0	1.1	0.0	0.0	0.0	0.0	0.0	80.7	0.0	105.2
Shenzhen	33.8	0.3	10.0	0.0	0.2	9.8	0.0	0.0	0.0	3.1	26.7	0.0	84.0
Guangzhou	33.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	22.2	0.0	57.6
Tianjin	31.5	0.5	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	20.7	0.0	52.9
Xi'an	31.5	0.3	10.0	0.1	0.0	7.3	0.0	1.0	0.0	0.0	0.0	0.0	50.3
Hangzhou	22.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	24.8	0.0	48.9
Wuhan	31.5	0.5	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.0
Qingdao	33.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.2
Xiamen	31.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	31.9
Ningbo	22.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	24.1
Zhuzhou	31.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.7
Huzhou	22.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	23.3
Xiangtan	31.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.7
Chongqing	31.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	36.0
Changsha	31.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.7
Nanchang	25.0	0.3	0.0	0.0	0.1	4.2	0.0	0.0	0.0	0.0	0.0	1.3	31.0
Linyi	18.9	0.5	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.1	0.0	0.0	23.0
Nanjing	15.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	17.3
Nantong	15.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	15.3
Lanzhou	18.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	19.8
Chengdu	18.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	19.6
Haikou	18.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	20.7
Shijiazhuang	15.8	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.1	16.6
Kunming	15.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.9
Hefei	0.0	0.3	0.0	0.1	0.0	7.8	0.0	0.0	0.0	3.6	0.0	0.0	11.9
Wuhu	8.0	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	8.5
Yichun	0.0	0.3	0.0	0.0	0.0	7.7	0.0	0.0	0.0	0.1	0.0	0.0	8.1
Taiyuan	20.0	0.3	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.4	0.0	0.0	29.1
Beijing	31.5	0.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	130.0	0.9	163.9
Zhengzhou	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3

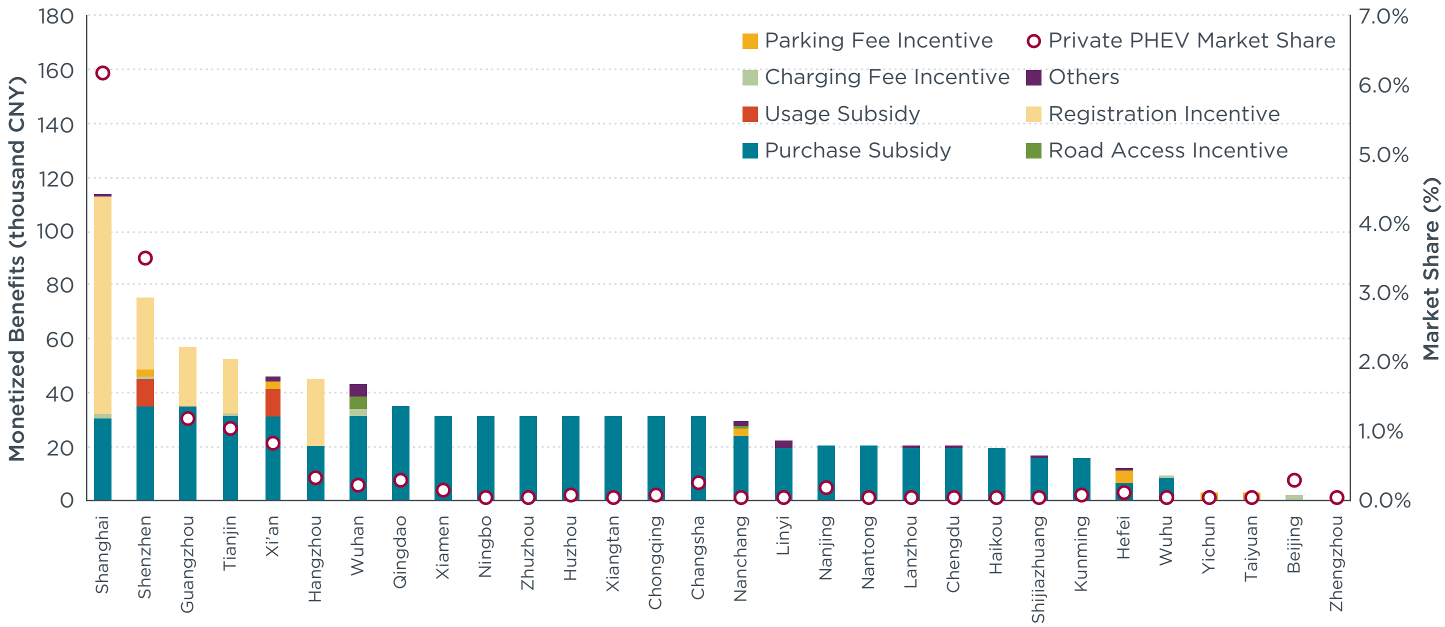

Figure 15. Private PHEV market share and monetized benefits to consumers (cities are ordered according to the magnitude of monetized benefits provided to private PHEV consumers)

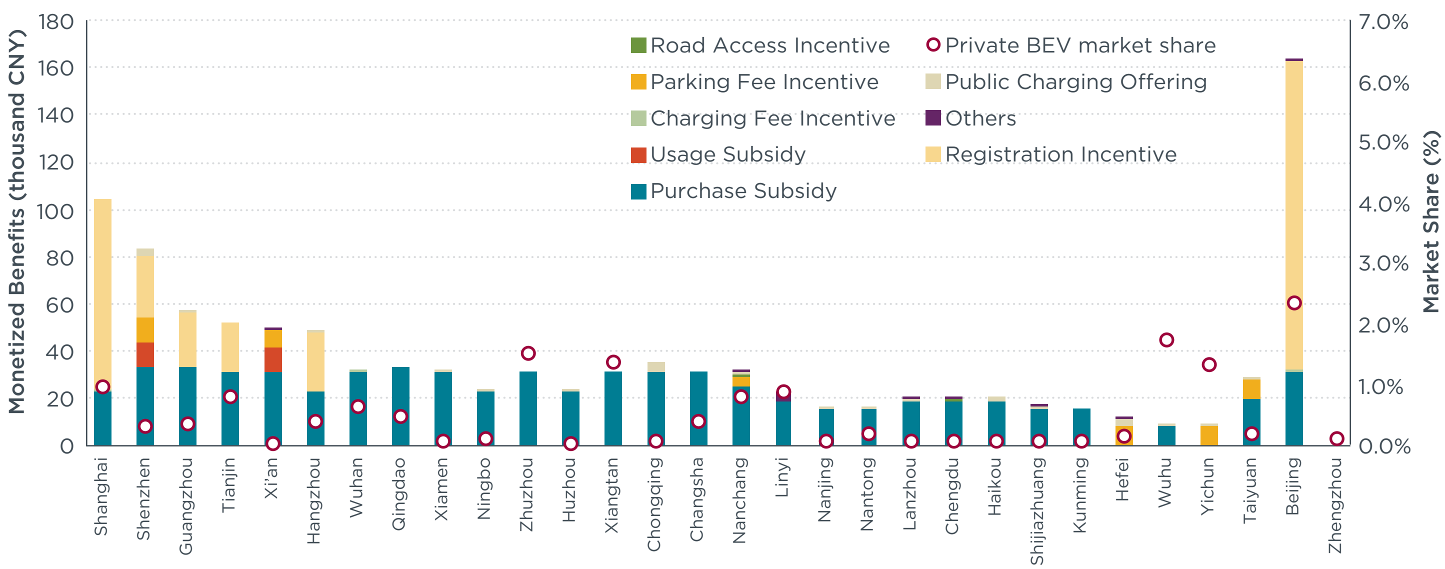

Figure 16. Private BEV market share and monetized benefits to consumers (cities are ordered according to the magnitude of monetized benefits provided to private BEV consumers)

For both vehicle types, the primary quantified market stimuli were vehicle purchase subsidy and registration (license plate) incentives, followed by a group of policies with moderate influence including parking fee reductions, charging fee incentives, road access incentives, and vehicle usage subsidies. The rest of the quantified policies—annual vehicle tax exemption or reduction, license fee waiver, car insurance incentive, and road toll reduction—translated into some value to consumers, but do not play a significant role in the overall incentive package. Public charger availability also positively affected battery electric car market penetration by reducing travel cost due to lack of electric range confidence. But this effect was not reflected for plug-in hybrid cars.

Evidently, direct vehicle purchase subsidies were the most widely used, influential stimulus across all regions. Only Zhengzhou did not deploy this policy measure. It appeared that BEVs did not receive any purchase subsidy from Hefei and Yichun, and the latter also zeroed the subsidy for PHEVs. The reason was that the representative BEV and PHEV models in this study did not meet the minimum thresholds in these two cities for the subsidy. Most cities provided an equal amount of purchase subsidies to both BEVs and PHEVs. Seven cities (Shanghai, Shenzhen, Guangzhou, Ningbo, Huzhou, Nanjing, and Nantong) provided higher subsidies for a typical PHEV than BEV. Three cities (Hangzhou, Taiyuan, and Beijing) did the opposite; in particular, Beijing and Taiyuan subsidized only BEVs. For cities offering the subsidy to both technologies, the mean subsidy levels for BEVs and PHEVs were close, at 21,700 and 21,500 *yuan*, respectively.

Vehicle registration incentives also were found to have prominent value to consumers. Among the six cities that adopted this measure, only Beijing treated BEVs and PHEVs differently, offering the extremely high incentive of 130,000 *yuan* to BEVs with nothing for PHEVs. The impact of this policy was immense in the most congested cities, like Beijing and Shanghai, where the subsidies approached—and in some cases even exceeded—the market value of the vehicles.

The purchasing subsidy was commonly perceived among many electric vehicle stakeholders as a "silver bullet" to drive the electric vehicle market. Our study clearly showed that the policy, alone, could not explain the variation in local electric vehicle market uptakes. It was the overall package of multiple direct and indirect incentives that played a collective role in boosting electric car sales in the private market. The full menu of stimuli for private consumers to deploy electric cars can be tremendous. Shanghai provided the greatest overall incentive at about 113,000 *yuan* to a typical PHEV owner. The top incentive for a typical BEV was evidenced in Beijing, at about 163,000 *yuan*.

It was found that monetary incentives and actions with a monetary value to consumers were linked to sales shares of both private battery electric and private plug-in hybrid cars, even though the visual trend was clearer for PHEVs but not so much for BEVs. Key statistical parameters shown in Table 12 suggested that total monetary value of consumer incentives was a significant predictor (with *p-value* less than 0.05) of vehicle market shares of private BEVs and PHEVs. However, the linear trend line for PHEV-incentive correlation was found to have a greater R^2 value than that for the BEV trend line, meaning there are possibly other uncaptured factors affecting the private BEV market.

Table 12. Statistical parameters of linear regression between PHEV/BEV market share and monetary value of consumer incentives

Dependent variable	Independent variable	*p*-VALUE	R^2
Private PHEV sales share	Monetary value of consumer incentives	0.007	0.74
Private BEV sales share		9.3^10(-10)	0.22

To further probe into the other possible explanatory factors, we examined the correlations between a few additional indicators—the share of fleet electric cars, number of promotion actions undertaken, vehicle model offering and availability, local market openness, charging convenience—and private BEV market performance. Our hypotheses are as follows.

Both the share of fleet electric cars and the number of electric vehicle promotion actions undertaken by a city government are used as indicators for public awareness of electric cars. As previously mentioned, China's new energy vehicle pilot programs were initiated in the public service fleet, which is to say buses and civil service trucks, then gradually spread to fleet and private users. Application of electric vehicles in these public and semi-public fleets may create a demonstration effect to the private consumers and help attract early adopters. The more policy measures announced and adopted for promoting electric vehicles, the greater the chance that the general public becomes acquainted with the relatively new technologies, therefore increasing consumer acceptance of these vehicles.

Model availability is believed to have had noticeable effects in the private electric car market in the United States because consumer preferences for vehicle model vary widely (National Research Council, 2015). Greater electric car model availability offered in one market may increase the appeal to new consumers who would otherwise purchase a conventional car for their specific utility demand.

The market openness index here measures the level of free market and competition in a city for both local and non-local electric vehicle brands. A fully open market does not include any regulatory or market barriers, expressed or implied, for electric car models produced by non-local manufacturers. Open and free markets benefit consumers with wide options for electric car products and set an environment for improved product performance and services by enhancing competitive pressures. In this study, we use the ratio between non-local and overall electric car sales of a city to indicate local market openness.

At the current stage of electric vehicle uptake, range anxiety remains a critical barrier for the adoption of electric cars. Greater charging availability increases user confidence and makes greater range and functionality possible. In this study, we use the number of chargers per million population to indicate charger distribution density, as a proxy for charging availability.

Results are shown in Figure 17. Interestingly, it appeared neither the hypothetical factors individually nor all of them jointly could explain the sales pattern of private battery electric cars. However, model availability and market openness were found to be closely correlated. This is easy to interpret: As more players were in the market, they brought a greater diversity of car models. In addition, the charging availability data were largely incomplete due to data limitation. Therefore, unfortunately, in this study we are not ready to draw clear a conclusion regarding the contribution of charging facility availability to local electric car markets. This experiment showed that there were still many remaining factors not captured here that also strongly influence electric car share in the private market.

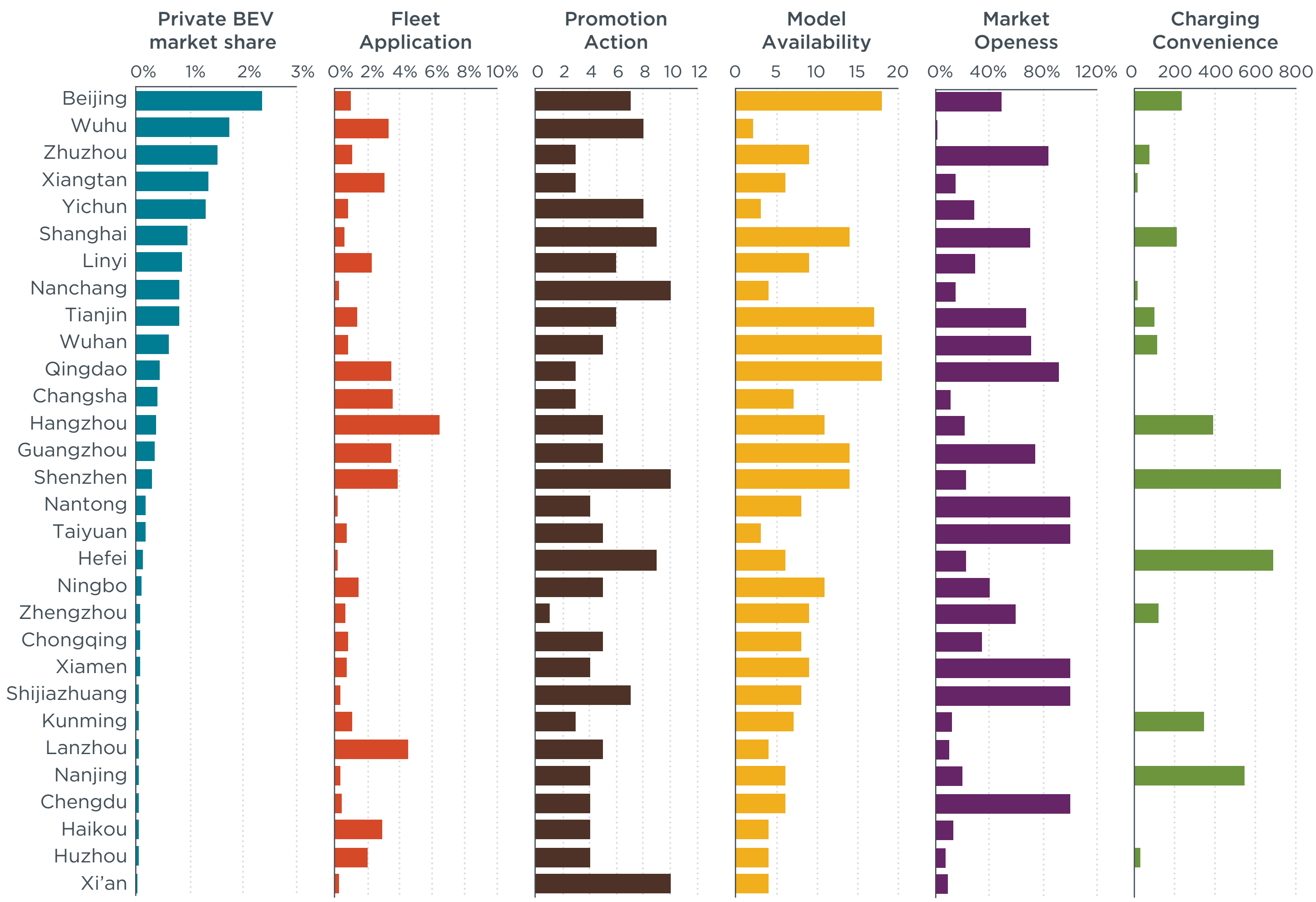

Figure 17. Private battery electric car share, public electric car share, number of promotion actions, model availability, market openness, and charger density in 30 cities.

5.2 IMPACT OF FLEET PROGRAMS

Figure 18 plots two sets of data. One set, on the left, shows the overall share of electric cars and share of electric cars integrated in various local fleet programs in the 30 cities. The other set of similar data for battery electric cars only is on the right. The fleets in our context include taxis, car-sharing fleets, and incentivized group acquisition and electric car rental fleets. The figure shows that the fleet program generated a remarkable result in increasing electric car—and especially battery electric car—deployment in cities. The top 10 cities with leading battery electric car shares had all adopted some form of fleet programs, as previously discussed. In these cities, the majority of BEV deployment was attributable to the fleet application. In four cities—Hangzhou, Lanzhou, Shenzhen and Guangzhou—more than 90% of BEVs were in the fleet.

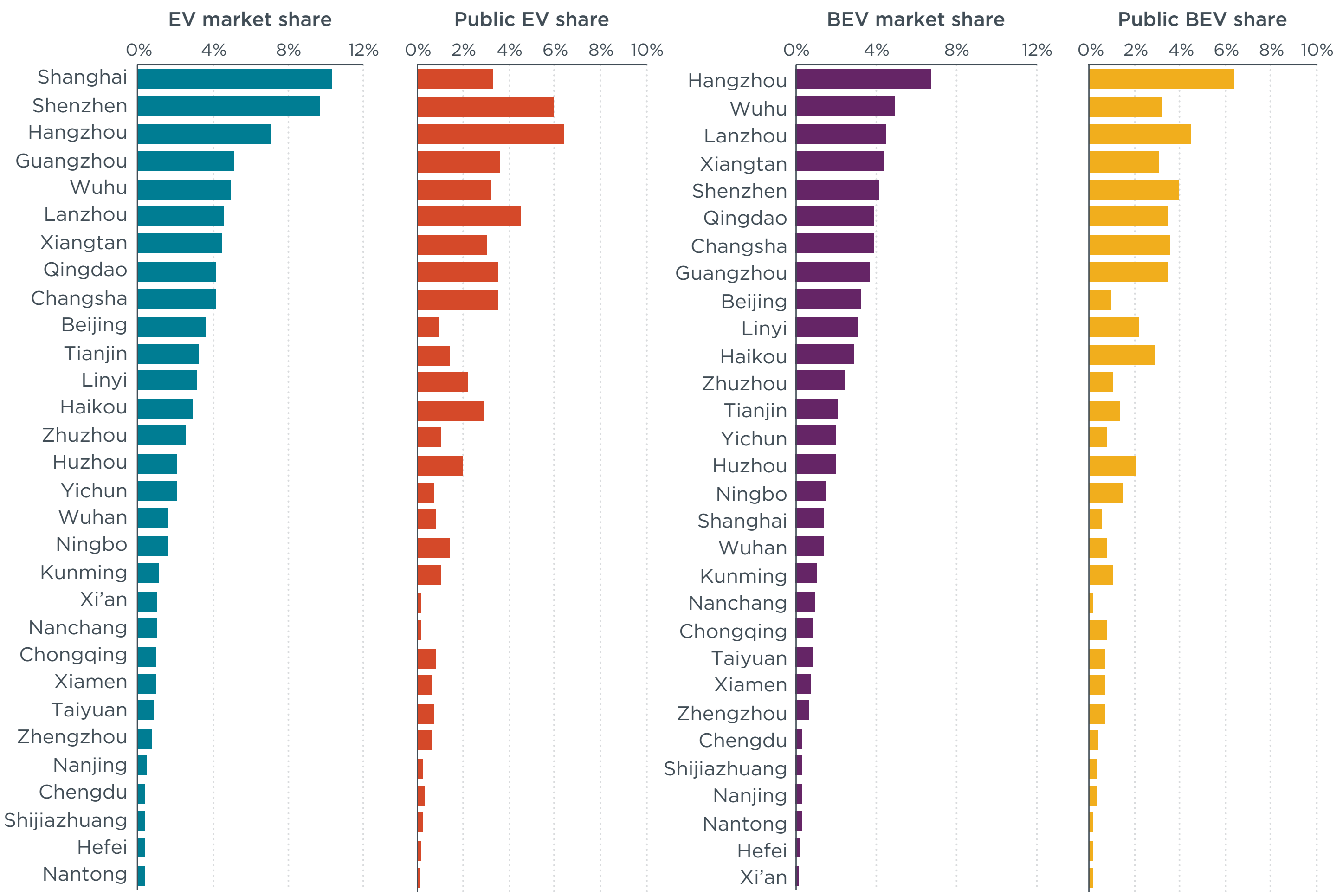

Figure 18. Overall EV/BEV share, and public EV/BEV share in 30 cities.

5.3 SEMI-QUALITATIVE RATING

In this subsection, we compile all factors evaluated for local electric car markets, including those affecting private consumers and fleet operators, and rate the cities against these factors using a semi-qualitative approach (Figure 19). Cities receiving a strong (red dot) rating for a particular parameter are indicated for the cities ranked in the top 10 for this factor. A weak rating (grey dot) refers to the bottom 10 cities for a given parameter. A moderate rating points to cities ranking in the middle. The semi-qualitative rating zooms out from the detailed quantitative analysis provided in the previous sections. Comparing these ratings with electric car market shares presented to the left in Figure 19 helps provide a big picture view of the common traits of the cities most and least successful in promoting electric cars.

City	Consumer benefits	Fleet programs	Model availability	Action numbers	Market openness	Public charger availability
Shanghai	Top 10	Top 10	Top 10	Top 10	Top 10	Top 10
Shenzhen	Top 10	Top 10	Top 10	Top 10	Middle 10	Top 10
Hangzhou	Top 10	Top 10	Top 10	Middle 10	Middle 10	Top 10
Guangzhou	Top 10	Top 10	Top 10	Middle 10	Top 10	
Wuhu	Bottom 10	Top 10	Bottom 10	Top 10	Bottom 10	
Lanzhou	Bottom 10	Top 10	Bottom 10	Middle 10	Bottom 10	
Xiangtan	Middle 10	Top 10	Bottom 10	Bottom 10	Bottom 10	Bottom 10
Qingdao	Top 10	Top 10	Top 10	Bottom 10	Top 10	
Changsha	Middle 10	Top 10	Middle 10	Bottom 10	Bottom 10	
Beijing	Top 10	Middle 10	Top 10	Top 10	Middle 10	Middle 10
Tianjin	Top 10	Middle 10	Top 10	Top 10	Middle 10	Middle 10
Linyi	Middle 10	Middle 10	Top 10	Top 10	Middle 10	
Haikou	Middle 10	Top 10	Bottom 10	Middle 10	Bottom 10	
Zhuzhou	Middle 10	Middle 10	Middle 10	Bottom 10	Top 10	Middle 10
Huzhou	Middle 10	Middle 10	Bottom 10	Middle 10	Bottom 10	Bottom 10
Yichun	Bottom 10	Middle 10	Bottom 10	Top 10	Middle 10	
Wuhan	Top 10	Middle 10	Top 10	Middle 10	Top 10	Bottom 10
Ningbo	Middle 10	Middle 10	Top 10	Middle 10	Middle 10	
Kunming	Bottom 10	Middle 10	Middle 10	Bottom 10	Bottom 10	Middle 10
Xi’an	Top 10	Bottom 10	Bottom 10	Top 10	Bottom 10	
Nanchang	Middle 10	Bottom 10	Bottom 10	Top 10	Bottom 10	Bottom 10
Chongqing	Top 10	Middle 10	Top 10	Middle 10	Middle 10	
Xiamen	Middle 10	Bottom 10	Top 10	Middle 10	Top 10	
Taiyuan	Middle 10	Bottom 10	Bottom 10	Middle 10	Top 10	
Zhengzhou	Bottom 10	Bottom 10	Top 10	Bottom 10	Middle 10	Bottom 10
Nanjing	Bottom 10	Bottom 10	Middle 10	Middle 10	Bottom 10	Top 10
Chengdu	Bottom 10	Bottom 10	Middle 10	Middle 10	Top 10	
Shijiazhuang	Bottom 10	Bottom 10	Top 10	Top 10	Top 10	
Hefei	Bottom 10	Bottom 10	Bottom 10	Top 10	Middle 10	Top 10
Nantong	Bottom 10	Bottom 10	Middle 10	Middle 10	Top 10	

● Top 10 ● Middle 10 ● Bottom 10

Figure 19. Electric car market shares and rating of various parameters in 30 cities.

As Figure 19 illustrates, cities with leading electric car market shares, such as Shanghai, Shenzhen, Hangzhou, and Guangzhou, tend to rank high on nearly all of the indicators, meaning they relied on a full menu of measures to promote electric cars. Cities with minimal electric car markets, including Zhengzhou, Nanjing, Chengdu, Shijiazhuang, Hefei, and Nantong, had two things in common—they neither gave sufficient monetary incentives to private consumers nor promoted fleet programs. Cities with minor and moderate electric car markets vary widely in their promotion strategies. But in general, their policy portfolios were not as comprehensive as those in the top markets. A few outliers—Wuhu, Xiangtan, and Lanzhou—focused on a single measure of promoting fleet application, but lacked actions in all other aspects. This unique strategy, nevertheless, helped position these cities among those with strong electric car market performance.

6 CONCLUSIONS

This study uses 2015 subnational market data in 30 new energy vehicle pilot cities to reveal general trends of electric car deployment at local levels. In addition, it seeks to comprehensively catalogue governmental actions that were spurring these cities' markets and identify the driving forces behind the success of the leading cities. The assessment focuses on the passenger car sector and the 30 cities that were showing commitment and early success in developing the electric cars, and offers several primary conclusions.

Cities were the frontier of pushing for electrification. Following China's top-down macro design of its vehicle electrification advancement path, cities had been shouldering the major responsibilities in electric vehicle development from the very beginning. Guided by the central government, and sometimes provincial governments as well, cities develop goals and plans, and formulate and implement a suite of policies to support them. Cities were also where the most innovative and aggressive policy measures were incubated and spearheaded. Eighteen of the 30 cities studied had set clear targets for electric vehicle deployment and charging infrastructure development. One of the more powerful policy tools driving the electric car market was giving electric vehicle owners privileges in acquiring license plates. Also, EV-based urban micro public transit system were innovated and piloted in cities.

A comprehensive suite of policy actions was adopted by cities to promote electric cars. The 30 cities in our study deployed more than 20 policy actions, including direct subsidies and tax deductions, incentives that indirectly provide monetary value to consumers, and preferential measures for electric car fleet application. The most prevalent policies (adopted by more than 10 cities) were new vehicle purchase subsidies, exemption/reduction of annual vehicle tax for electric cars, and providing adequate charging facilities. Other major policies were car-sharing programs (nine cities), charging fee reductions (seven cities), license plate/registration privileges (seven cities), parking fee incentives (six cities), road access privileges (six cities), taxi fleet purchase incentives (five cities), and group purchase subsidies (five cities), respectively. Each having 10 policy actions, Shenzhen and Xi'an were the most aggressive in government efforts of promoting electric cars, in terms of the number of policy actions undertaken.

Electric cars were being deployed disproportionally in the country. The top 30 cities represented only 26% of auto sales, but they made up 84% of electric car deployment in the entire country. In 2015, the average market penetration of electric cars in these cities was 2.7%, significantly greater than the national average of 0.8%. Great disparities were also found among the 30 cities, from more than 10% electric car market penetration to below 1%. These observations underscore the importance of city-based actions in promoting electric cars.

Various forms of fleet programs were the main driver of local electric car markets in many leading cities. Primarily determined by China's national strategies toward vehicle electrification, application of electric vehicles was first established in the civil service sector, with buses, city sanitation vehicles, and postal trucks, then gradually spread to fleet and private users. Sixteen cities in our study aggressively promoted electric car deployment in the fleet, which includes taxis, car-sharing fleets, and incentivized group acquisition and electric car rental. Electric cars in these 16 cities, on average, took up 4.4% of local new passenger car market, higher than the average electric car market share of 2.7% for the 30 cities. In four cities—Hangzhou, Lanzhou, Shenzhen and Guangzhou specifically—more than 90% of BEVs were in the various fleets mentioned above. A few cities innovated a micro public transit program composed solely of electric cars, a variation of the mainstream car-sharing adopted in other parts of the world.

Incentives remain a key part of driving the private market for electric vehicles. Greater monetary value of the full policy package offered in a city was found to evidently correlate with higher market share of private plug-in cars. The incentives include both financial and nonfinancial policy actions.

New vehicle registration incentives in mega cities were the major appeal to private consumers. In these 30 cities, direct vehicle purchase subsidies had little explanatory power with regard to local electric vehicle market performance. Instead, we found that mega cities used new vehicle registration incentives, specifically designating more license plates for new electric cars, as the major appeal to private consumers. Six cities in our study, namely Shanghai, Beijing, Guangzhou, Tianjin, Hangzhou, and Shenzhen, adopted this policy. These cities imposed an upper limit on total new vehicle registration to help relieve urban congestion. New vehicle owners must enter a lottery or auction system to be able to obtain a license plate, which has considerably increased the cost of owning a new car. Notwithstanding, in these highly urbanized and affluent cities, owning a car has become a way of life for many middle-class citizens. The strong demand for new cars and increasingly precious license plate quota has largely driven up the explicit, or hidden, monetary value of a license plate to as much as 130,000 *yuan*. This is more than the list price of a typical battery electric vehicle in China; for example, that is 19% more than the price of a Zhidou E20, the best-selling BEV in these 30 cities in 2015. As cities were either exempting or treating electric cars preferentially in their license plate quota systems, electric car owners were enjoying this huge privilege that would save them money or time compared to buying a conventional car.

A comprehensive package of local policies is key to unlocking the electric car market. In this study, multiple indictors were examined to identify motives behind electric car uptake. A semi-qualitative rating against these factors across 30 cities showed that cities with the most comprehensive portfolio of actions to provide sufficient consumer incentives, enable and support fleet programs, expand consumer exposure to electric technologies, enrich model availability, ensure an open market and charging convenience were experiencing greater success in accelerating their passenger car fleets to electrification. By comparison, cities strongly promoting one or two elements while missing other ingredients encountered market deficiency of electric cars to various extents.

Manufacturers have seen fewer barriers in selling in their home markets. Despite the central government's relentless effort in forestalling local market protectionism since the initial design of its major policies toward electric vehicles, this study showed that the results were largely ineffective. In 16 of the 30 cities we studied, local electric car markets were dominated by the local brands. Local protection took many hidden forms, including customizing the qualification threshold for vehicle purchase subsidies with technical parameters that only local brands could pass.

This study also offers other valuable observations of electric car market patterns in China. We found that investment and resource allocation toward electric vehicles were more prominent in cities with potent political and economic influences (cities often classified as Tier 1 or new Tier 1 cities). These cities tended to offer greater incentives to stimulating their electric car markets and often experienced greater EV adoption. Although vehicle electrification was claimed as an antidote to urban air pollution in many Chinese regions, subnational data show the connection between electric car uptake and local air pollution relief has yet to be established. Also, consumers in many smaller Chinese cities had a clear preference to micro battery electric cars.

Finally, this study points toward many unanswered questions that warrant frequent updates of similar assessments of electric car submarket data and local policy actions. Some cities in this report have been implementing a substantial number of policies, but without yet seeing noticeable electric car deployment. Despite the strong correlation between consumer incentives and the private consumer market for plug-in hybrid cars, that link still remains fuzzy for battery electric cars. In addition, demographics and income are important factors that were not explored in detail in this study. Lastly, the charging infrastructure data in this study were largely incomplete, and therefore we are not ready to draw clear conclusions about the contribution of charging facility availability to local electric car markets. However, our recent analysis more than 350 metropolitan areas worldwide identified public charging infrastructure as statistically linked with greater EV uptake (Hall & Lutsey, 2017), which may warrant further investigation into the situation in China. In general, the year of 2015 was transitional for the Chinese plug-in electric car market and many trends remain unclear. With updated data on new electric car sales, charging infrastructure, and other supplemental demographics in 2016 and later years will help better reveal those trends.

Electrification in the mobile source application is believed to be a promising solution for oil conservation, local air quality improvement, climate change mitigation, and industrial upgrading. Governments around the world have been acting progressively to overcome barriers and develop electric vehicle markets. Although the evolution of technology is an increasingly globalized process, market stimulation policies must be based primarily on local circumstances. The several major policy innovations by the Chinese cities studied and documented in this work add to the constantly growing global playbook of policies and contribute to finding the key ingredients to unlocking the electric vehicle markets in the remaining regions in China.

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