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ASSESSMENT OF LEADING NEW ENERGY VEHICLE CITY MARKETS IN CHINA AND POLICY LESSONS

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ABOUT CHINA EV100

China EV100 is a nonprofit organization and third-party think tank aiming to encourage the development of the electric vehicle industry. By providing a platform without boundaries across industries, disciplines, ownership, and departments, it promotes convergence and collaborative innovation across multiple fields through research and communication.

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EXECUTIVE SUMMARY

Cities are at the frontier of new energy vehicle (NEV) deployment in China and are often where cutting-edge vehicle and charging technologies, business models, and policies are tested. In China, the term NEV encompasses battery-electric, plug-in hybrid, and hydrogen fuel cell electric vehicles. Through comprehensive analysis of market data covering 2015 to 2020, we identified leading city-level NEV markets for passenger cars and various types of commercial vehicles in China. This paper assesses their market characteristics and considers the factors underlying their success, with example cases.

Leading cities were selected based on annual market share for new energy passenger cars (NEPCs) and on the absolute number of registrations per year for the new energy commercial vehicles (NECVs). This difference in approach is to avoid skewed results: Because some commercial vehicle markets are quite small, these might show an extremely high share of NECVs in cases where only a few dozen commercial vehicles were sold in all.

Wherever illuminating, this study also compares NEV market characteristics by China's city tier system, a well-established but unofficial way of grouping over 300 cities into six tiers based on population, economic output, and other business and development factors. Generally, cities in the same tier are similar in terms of socio-economic indicators such as gross regional product, per-capita income, and population. The smaller the tier number, the bigger and more affluent the city. Beijing, Shanghai, Shenzhen, and Guangzhou are the Tier 1 cities. The next level, New Tier 1 cities, are large, often provincial-level cities or capital cities approaching Tier 1 cities in one or more aspects; these are Tianjin, Chongqing, and Chengdu of Sichuan province, Hangzhou of Zhejiang province, and 11 other cities. Tier 2 cities are mainly provincial capitals or cities in eastern China with robust economic vitality, such as Hefei of Anhui province and Xiamen of Fujian province. Tier 3 cities are typically those with a relatively strong economy, big population, and strategic significance in their respective provinces, such as Sanya in Hainan province and Liuzhou in Guangxi Zhuang autonomous region. Tier 4 and 5 cities are mainly mid-to-small-size cities or prefecture- or township-level cities.

Our major findings for passenger cars are:

- Tier 1 and New Tier 1 cities still play a pivotal role in driving the market, but NEPC growth in Tier 2–5 cities had gained traction by 2020 (Figure ES.1).
- Consumer preferences vary widely across different tiers. Medium-size, longer-range, higher-end NEPC models dominated the larger city markets, while mini-size, more practical, more affordable models were most prevalent in smaller cities (Figure ES.2).
- Brand diversity has increased dramatically, and manufacturers sold to more markets beyond their home markets in 2020 than in 2015. This suggests that local market protectionism has mostly been rectified.
- Despite different development paths and strategies, all kinds of cities have successfully promoted electric mobility.
  - The Tier 1 cities offered various forms of direct fiscal incentives, including operational subsidies, charging subsidies, and waived parking premiums, and nonfiscal incentives such as registration and road access privileges. Additionally, these cities often invested more in building a convenient charging network for urban NEPC owners.
  - Smaller cities developed unique patterns of incentives, and some proved to be as successful as the Tier 1 cities in terms of NEPC market share. For instance, a cluster of Tier 3–5 cities in Guangxi

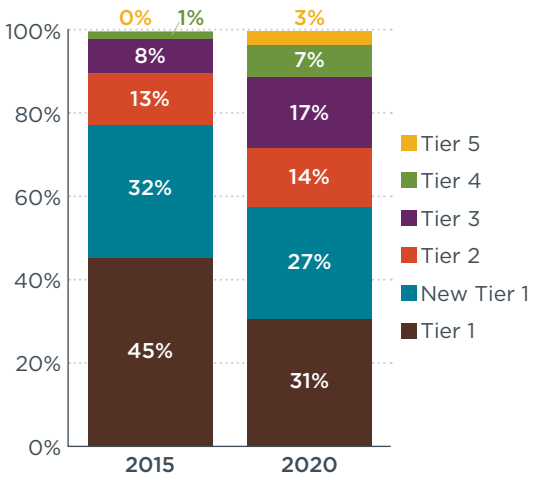

Figure ES.1. Share of new energy passenger car registrations by Chinese city tier in 2015 and 2020

*The range from Tier 1–5 starts with large, wealthy cities and progessively moves to smaller, underdeveloped cities

Zhuang autonomous region focused on promoting the local car brand, Wuling Hongguang. Additionally, the prefecture level city of Ningde, the manufacturing base of the world's leading NEV battery producer, CATL, leveraged its advantage in battery manufacturing and focused on building a complete supply chain and a supportive environment for the consumer market.

Figure ES.2 displays the details of the top five NEPC city markets in each city class where there are more than five cities in a given class.

Our major findings for commercial vehicles are:

- Buses and urban logistics vehicles currently dominate the NECV market. Heavier trucks only began to emerge after 2018, after the launch of major environmental campaigns.
- New energy models for all commercial vehicle types—urban logistics vehicles, dump trucks, tractor trucks, buses, coaches, and other utility vehicles—are now widely available, and range from a few hundred models for buses to a few dozen for the heaviest tractor trucks.
- For the commercial truck segments, besides the unrivaled records set by Shenzhen, leading city markets for new energy urban logistics vehicles are emerging in the Central Eastern (e.g., Nanjing) and Southwestern (e.g., Chengdu) regions, and for new energy dump truck and tractor trucks, leading cities are emerging in Northern China (e.g., Beijing, Yangquan, and Handan).
- Most cities were approaching a 100% new energy city bus market in 2020 (Shenzhen fully electrified its new bus fleet in 2017 and is not shown on the chart (ES.3) because there were not many new buses in 2020). For the coach segment, the market share of NEVs exceeded 20% in seven cities in 2020, and notably, Guangzhou deployed over 300 vehicles.
- Environmental policies played a pivotal role in driving the new energy truck market, and most leading cities are in the key regions identified in the *National Plan of Blue-Sky Defense.* Some of the policies set requirements for deploying new energy vehicles and others required the use of clean vehicles as part of the compliance package for reducing industry-wide pollution; this was often directly applied to heavy, polluting industries, and *Promoting an Ultra-low Emission Steel Industry* is an example of such. Innovative local policies and initiatives such as low-emission zones and green multimodal collaborations also helped to create a market for zero-emission trucks.

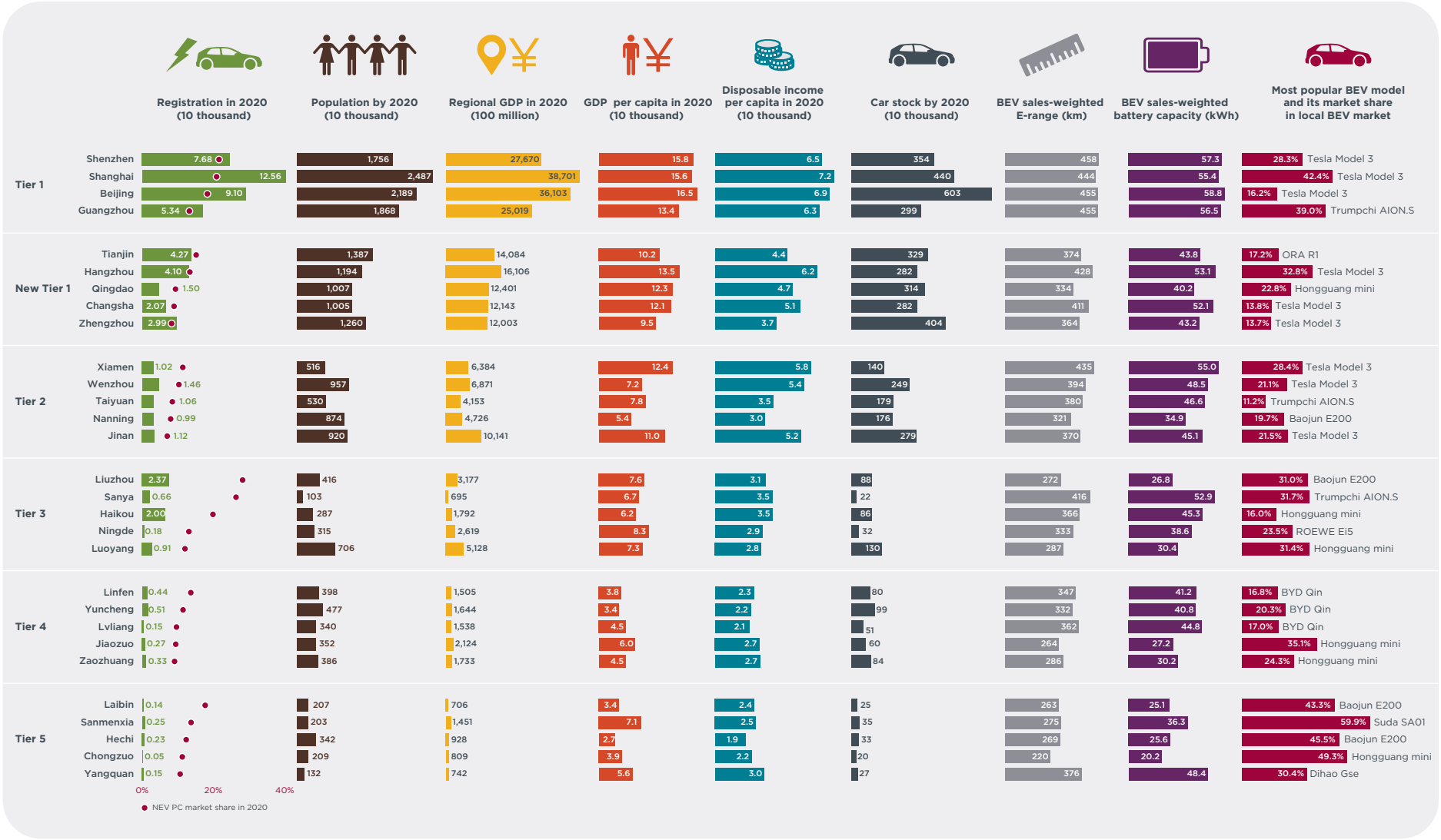

Figure ES.2. Top five cities in each city class with the highest new energy passenger car market penetration in 2020 and their select new energy vehicle market and socio-economic characteristics.

Figure ES.3 displays the top 10 NECV city markets in terms of new registrations in 2020 for various vehicle types.

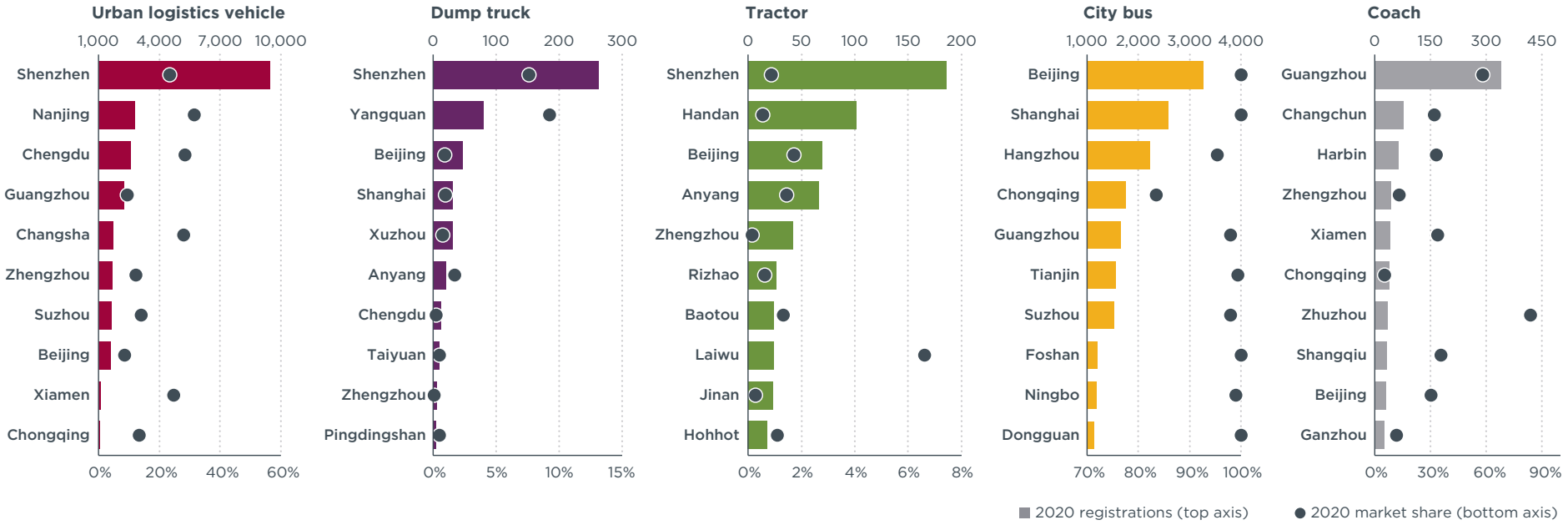

Figure ES.3. Registrations and market penetration in 2020 in the top 10 cities for various types of new energy commercial vehicles.

We also identified a few broad areas where China might increase investment and policy focus in the coming years to make more progress in developing its NEV market.

- *Urban and regional freight*. Cities and provinces still rely heavily on internal combustion engine vehicles for cross-region freight delivery and there is immense potential to utilize new energy trucks to fulfill local and regional freight transportation needs. The transition to electric is ripe for urban logistics vehicle fleets in terms of model availability, successful demonstrations from early movers, the presence of robust policy tools, and cost.
- *Northwestern and northeastern submarkets* are relatively underdeveloped. Cities in these regions might consider longer-range NEV models with appropriate thermal control, especially models that perform well in cities with similar, but less frequent, cold weather conditions, such as Beijing, Tianjin, and Changchun.
- *Tier 3–5 cities*. The accelerated urbanization and modernization process in small Chinese cities and towns will drive huge car demand. With proper policies and sufficient model availability, these cities can release massive potential for NEVs.
- *Equity of clean air*. Although passenger and freight transportation are significant sources of urban and regional air pollution, consumers in polluted cities and regions cannot always afford electric vehicles. Favorable policies such as fiscal incentives are therefore needed to tilt the market toward NEVs in these regions. Note, too, that in Western China, where hydropower is abundant, NEVs will be closest to net-zero carbon emissions on a life-cycle basis.

The successful experiences from the leading NEV cities we analyzed can educate other cities with similar characteristics in China and globally. Our high-level recommendations are:

- China can aim for higher NEV deployment targets for passenger cars and commercial vehicles. Referring to 2020's top-runner NEV city markets for each vehicle segment as a guide, China can consider the following 2025 NEV targets: 30% NEV share for new passenger cars, 60% for urban logistics vehicles, 50% for coaches, 10% for dump trucks, and 7% for tractor trucks.
- As national purchase subsidies phase out, cities can still exploit a wide range of indirect incentives to help bring their NEV markets to maturity. Examples of such are dedicated parking spaces, registration privileges, and preferential road or lane access. Additionally, there are opportunities to employ smaller, use-based incentives such as utility rate discounts, parking and charging service fee reductions, and zero-emission zones.
- Government and automaker partnerships are important for precisely understanding consumer needs and strategizing model rollout and policies. For example, Wuling's mini EVs, at a fraction of the price of a Tesla Model 3, cannot deliver the same 500 km electric range, but are sufficiently affordable, functional, and convenient to replace the gasoline motor scooters that used to be the dominant mobility of lower-income consumers.
- Electrification can be a win-win strategy for local economic development and better air quality in cities with an established automotive industry and supply chain, or a plan to nest one. Cities should invest in the technologies of the future—NEVs—rather than the technologies of the past.
- The decision-making bodies of cities can collaborate on coherent and complementary policy packages to promote NEVs. Different government agencies will each have their own unique power and authority. Environmental bureaus could require high-polluting industries to use clean transportation equipment and designate low- or zero-emission zones; transportation bureaus might favor NEVs for road access and/or registration; and industrial bureaus could set NEV development targets as part of local economic development plans.

Finally, although outside the scope of this analysis, we recommend policies to avoid or shift private, motorized travel to naturally zero-emission mobilities such as walking and biking where possible in cities and in densely populated areas.

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ACRONYMS

NEV	New energy vehicle
NEPC	New energy passenger car
NECV	New energy commercial vehicle
OEM	Original equipment manufacturer
ICE	Internal combustion engine
MOF	Ministry of Finance of the People's Republic of China

1. INTRODUCTION

Despite a temporary disruption caused by the COVID-19 pandemic, the new energy vehicle (NEV) market has experienced tremendous growth in recent years in China. Annual NEV sales increased by over four times from 2015 to 2020, and this period saw a compound annual growth rate of 33% (Sohu News, 2021a).

In China, the term NEV encompasses battery-electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hydrogen fuel cell electric vehicles (FCEVs), and cities were on the front lines of NEV market development. In 2020, nearly 70% of new NEVs in China, including passenger cars and commercial vehicles, were registered in 30 leading cities (Figure 1).[1] Additionally, from 2015 to 2020, NEV sales expanded from a handful of the mostly wealthy and prominent megacities to an increasing number of smaller cities. Both big and smaller cities have adopted innovative local policies and various other strategies suited to their local context to drive NEV sales.

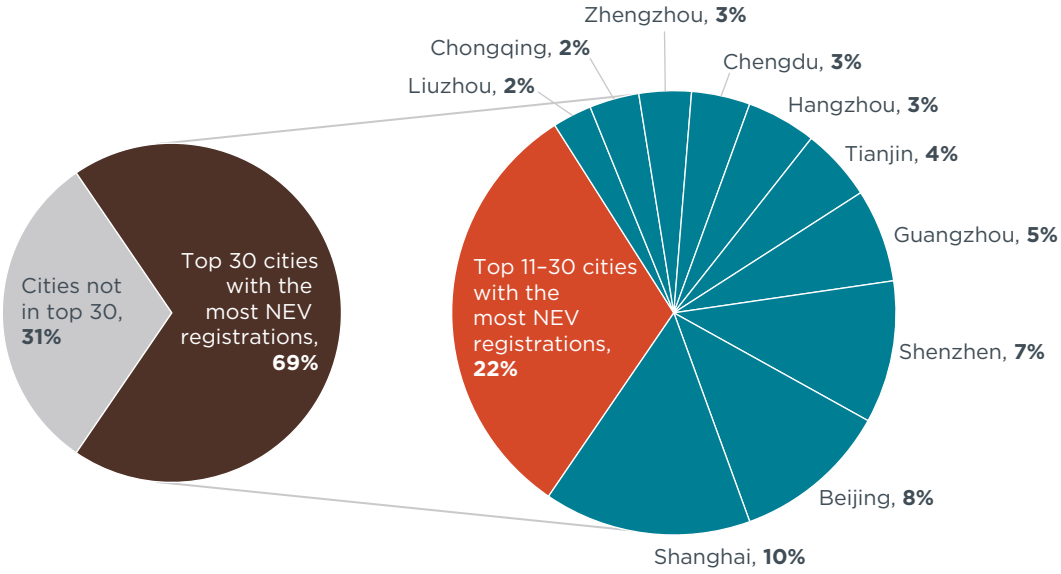


Figure 1. New energy vehicle registrations (passenger cars and commercial vehicles are included) in Chinese cities, 2020.

This study identifies the top NEV city markets for passenger cars and commercial vehicles to examine their characteristics in terms of aspects like use purpose of the vehicles, vehicle size preferences, leading brands, electric range distribution of NEVs, and more. To reflect the historical evolution and trends of NEV development in these local markets, we used data from 2015 to 2020.[2] Our analysis started with over 300 Chinese cities and then narrowed down the list to cities with the best NEV market performance and unique development strategies.

The rest of this paper is organized as follows. Chapter 2 analyzes the development of new energy passenger cars in Chinese cities and focuses on the most successful local NEV markets of different city classes. Chapter 3 assesses the development features of five types of new energy commercial vehicles (urban logistics trucks, dump trucks, tractor trucks, city buses, and coaches) in cities and highlights the leading local markets of each type. Chapter 4 considers the broad economic and policy factors that likely drove NEV development in these cities. In the last chapter, we conclude with our key findings and suggestions.

1 In China, passenger cars are four-wheel motor vehicles that carry people and have no more than nine seats (maximum designed gross vehicle weight ≤ 3,500kg); commercial vehicles are those exclude passenger cars, including trucks, buses, and utility vehicles.

2 All data used in this report is insurance data of vehicles produced domestically in China.

2. DEVELOPMENT OF NEW ENERGY PASSENGER CARS IN CHINESE CITIES

This chapter starts with market analysis of the 30 cities with the highest new energy passenger car (NEPC) sales (2020). It considers things such as vehicle segment preference and explores vehicle features such as electric range, leading brands, and more. We then examine and compare these market features by different city classes. Last but not least, we identify the five leaders in each city class, depict their NEPC market characteristics, and briefly discuss what seems to have driven their NEV development.

2.1. CHARACTERISTICS OF THE TOP 30 MARKETS FOR NEW ENERGY PASSENGER CARS

In 2020, the top 30 markets for NEPCs, led by Shanghai, Beijing, Shenzhen, Guangzhou, Tianjin, and Hangzhou, were home to 70% of the NEPC registrations in China (Figure 2).

Note that, back in 2015, when the private car market was still in its infancy, vehicle registration data did not differentiate personal purchases from other purchases in a broader non-commercial-use category. Except for a handful of NEV development pilot cities like Shenzhen and Shanghai (The State Information Center, 2017), the top 30 cities' NEPC markets in 2015 were primarily made up of government-procured vehicles, taxis, and vehicles in the ride-hailing fleet, either for non-commercial-use or commercial-use (Ministry of Finance of the People's Republic of China [MOF], 2009). In 2020, however, private NEPCs dominated city markets with an average of 71% of the NEV market, followed by commercial-use cars (17%), and then government or corporate fleets (12%).

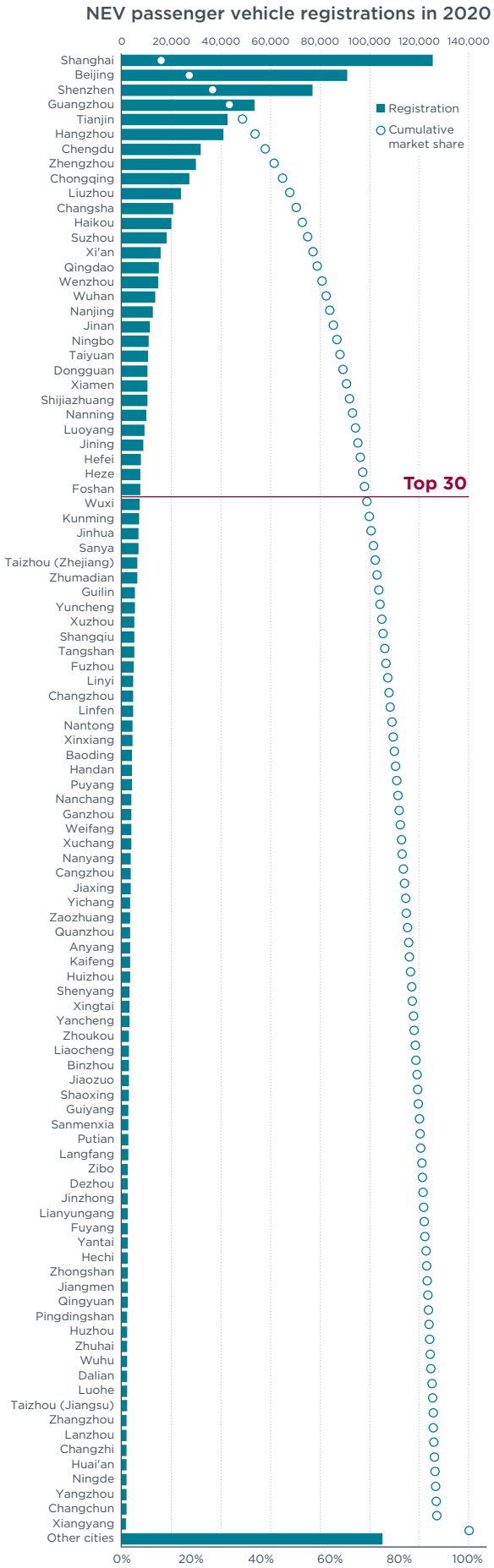


Figure 2. Annual new energy passenger car registration and cumulative market share of major cities in China, 2020.

As shown in Figure 3, the market share of private NEPCs varied across cities, ranging from 41% in Changsha (Hunan province) to 98% in Heze (Shangdong province). Notably, in Shenzhen, Liuzhou, Beijing, Nanning, Jining, and Heze, private NEPC shares all exceeded 80% in the year. Note, though, that some NEPCs registered as private were partially used for ride-hailing purposes via platforms such as DiDi; therefore, the actual share of purely private-use cars might be lower than shown (The Ride-Hailing Guide, 2020).

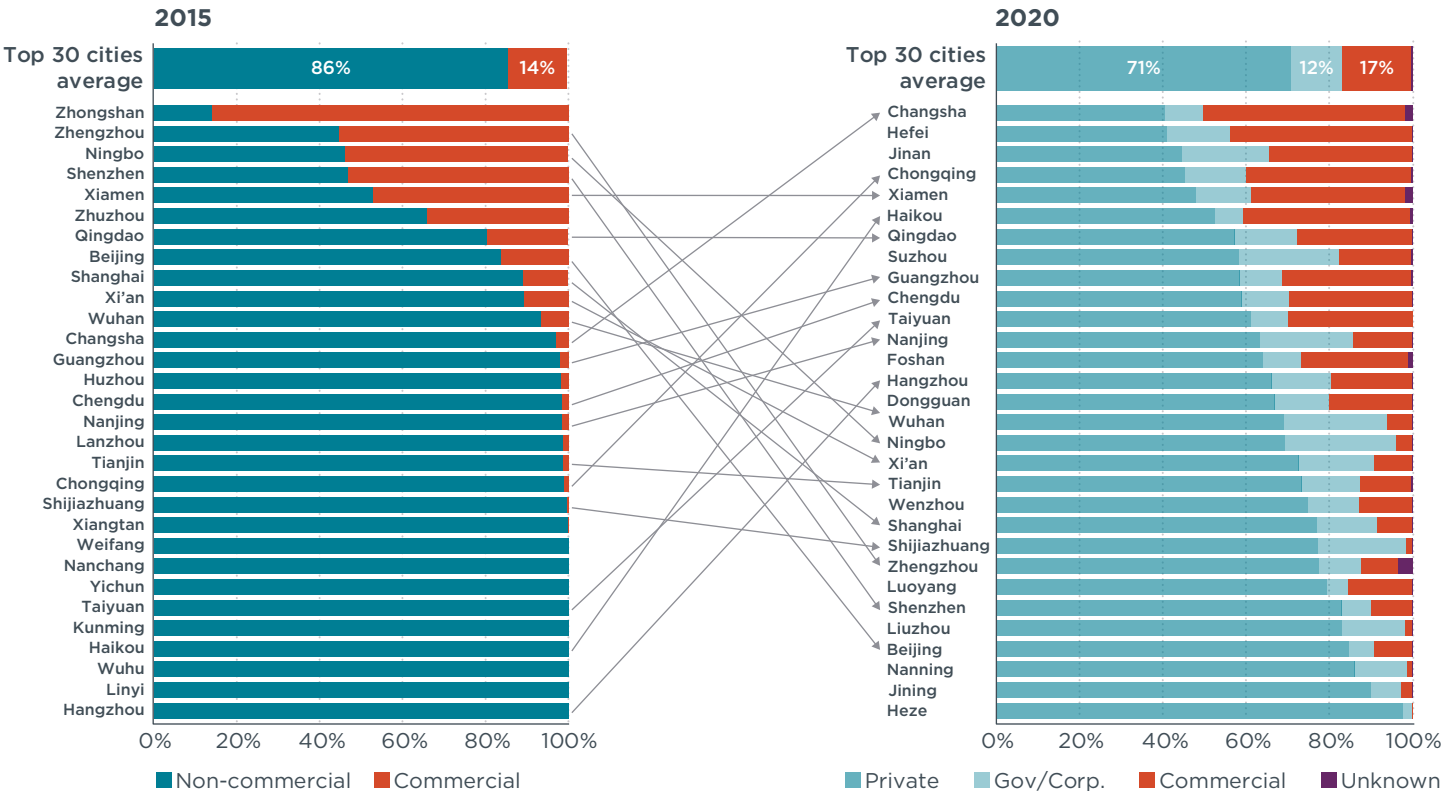


Figure 3. Composition of local new energy passenger car markets by ownership and usage type in 30 leading cities, 2015 and 2020.

* Cities are ranked by their non-commercial (2015) or private (2020) electric car shares.

Increasing consumer preference for bigger and more luxurious NEPCs was witnessed in recent years. As illustrated in Figure 4, below, in 2015, small-size NEPC categories (A00, A0, and A) accounted for 87% of the registrations in the leading city markets. By 2020, though, that shrank to 43%. Larger car categories, the B and C segments, were nearly nonexistent in 2015, but were about one-third of the market across the top 30 cities 5 years later. Additionally, the share of larger and higher-end sport utility vehicles (SUVs) and multi-purpose vehicles (MPVs) increased from 10% to 29% between 2015 and 2020 in these top 30 cities (Figure 4). Cities that most embraced these vehicles were Xi'an, Shenzhen, Tianjin, Xiamen, and Wuhan in 2015, and by 2020, it was Haikou, Wuhan, Nanjing, Suzhou, and Shenzhen.

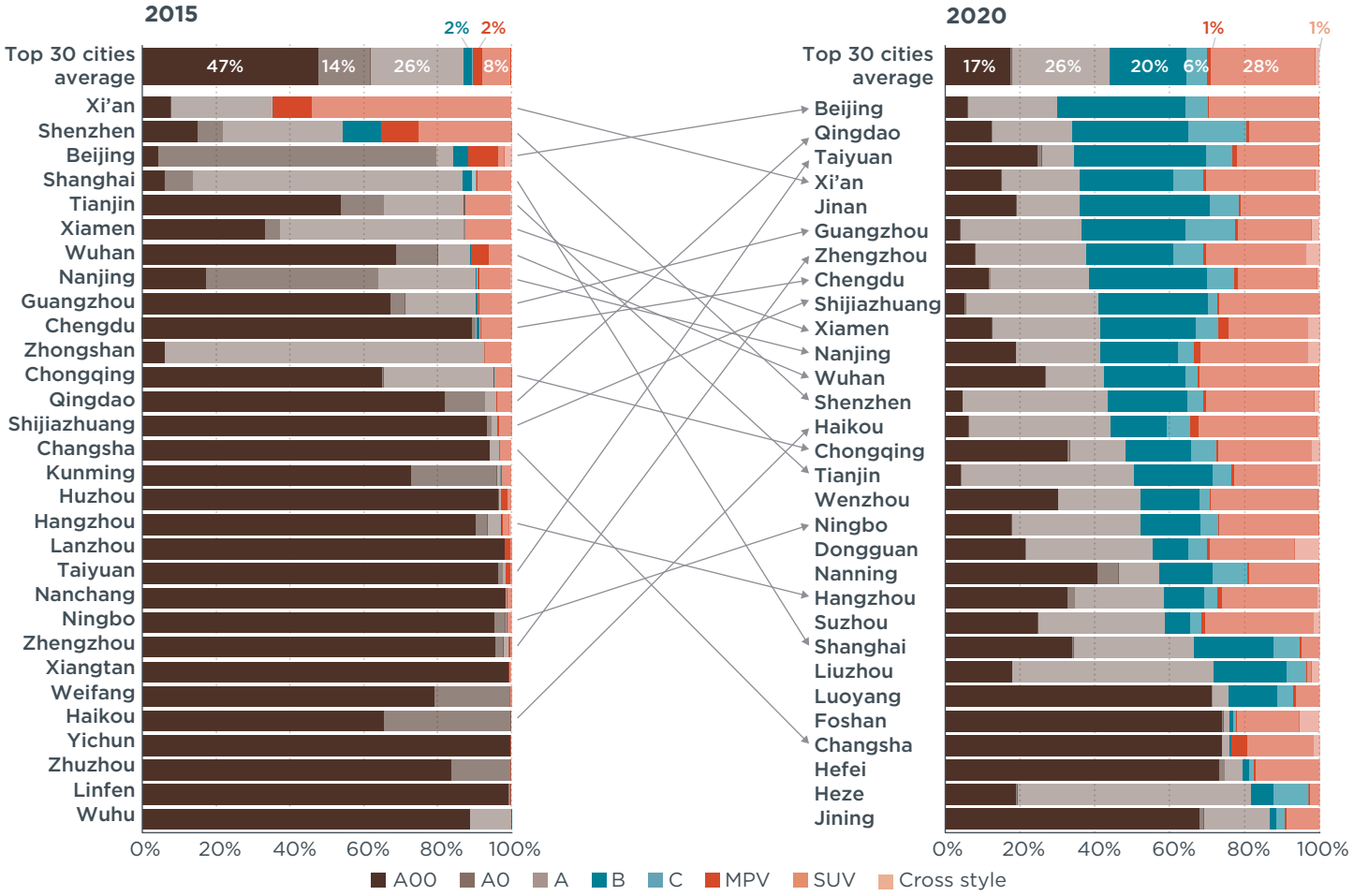


Figure 4. Composition of new energy passenger car markets in leading cities by vehicle segment, 2015 and 2020.

* Cities are ranked by small-size car (A00, A0, and A categories) shares.

Between 2015 and 2020, the average battery capacity and electric range of passenger BEVs in the top 30 local markets increased from 23 kWh and 164 km to 50 kWh and 407 km (Figure 5). The variation of electric range among the cities was apparent both in 2015 and 2020. In 2020, the average electric range in Shenzhen was 458 km, almost double that in Heze, Shangdong province. Similarly, in 2015, the average electric ranges in the 30 leading cities fell between 100 km and 240 km. Consumers in megacities tended to buy longer-range and more powerful NEPCs, and these variances can be explained mainly by the NEPC model preference across cities (see Figure 13 in Section 2.2).

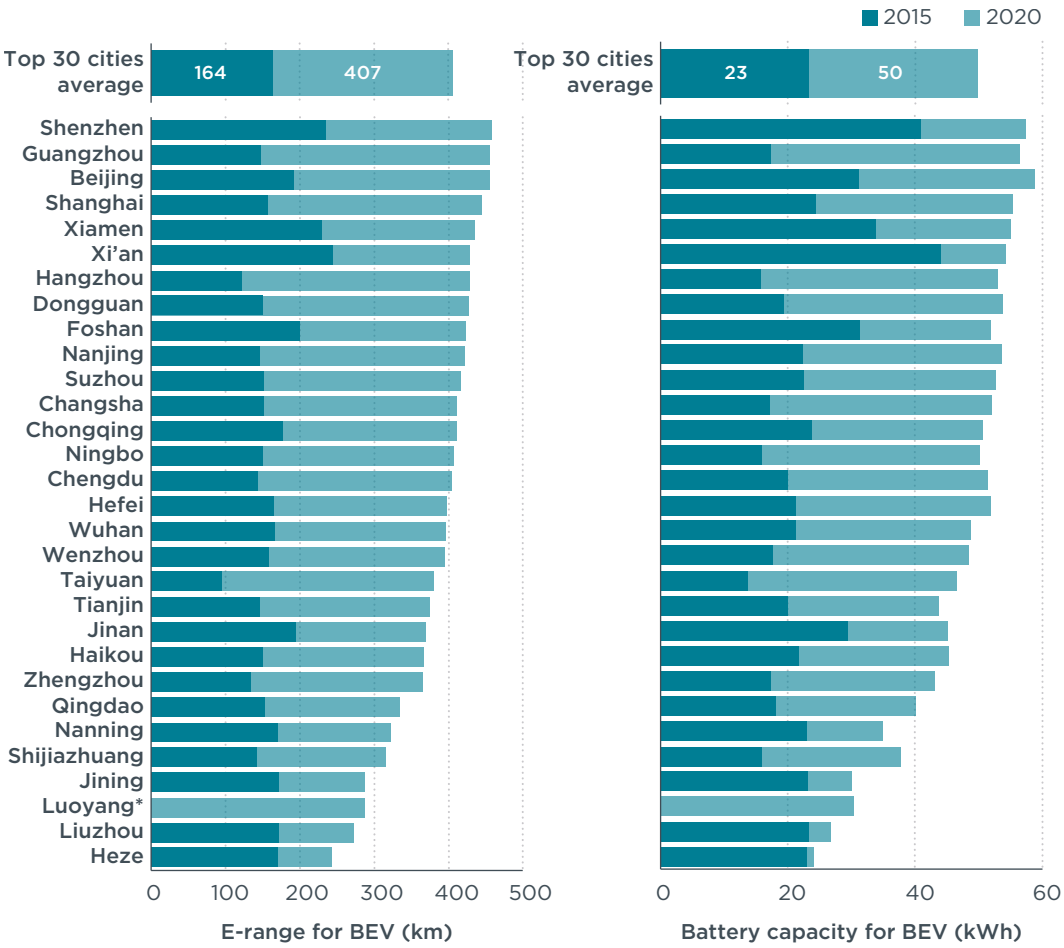


Figure 5. Average electric range and battery capacity of new energy passenger cars (BEVs only) in the 30 leading cities, 2015 and 2020.

*Luoyang had no BEVs registered in 2015 and thus does not have corresponding bar in the figure.

Figure 6 plots the spatial distribution of annual NEPC registrations in China and shows that NEPC deployment concentrated in Central, Eastern, and Southern China. The figure also shows that BEVs prevailed in all the leading cities. Only a few cities—Jinan, Shanghai, Xi'an, Shenzhen, and Shijiazhuang—had PHEV shares above 30%. Huge electrification potential remains in Western and Northern Chinese cities. These regions are either economically underdeveloped or have long stretches of cold weather (e.g., a few months below freezing on a monthly average basis, with a few dozen extreme days under -20 °C) that could possibly hinder the broad application of electric vehicles, or both. Cities in these regions might consider longer-range models with appropriate thermal control, especially models that perform well in cities with similar, but less frequent, cold weather conditions, such as Beijing and Tianjin.

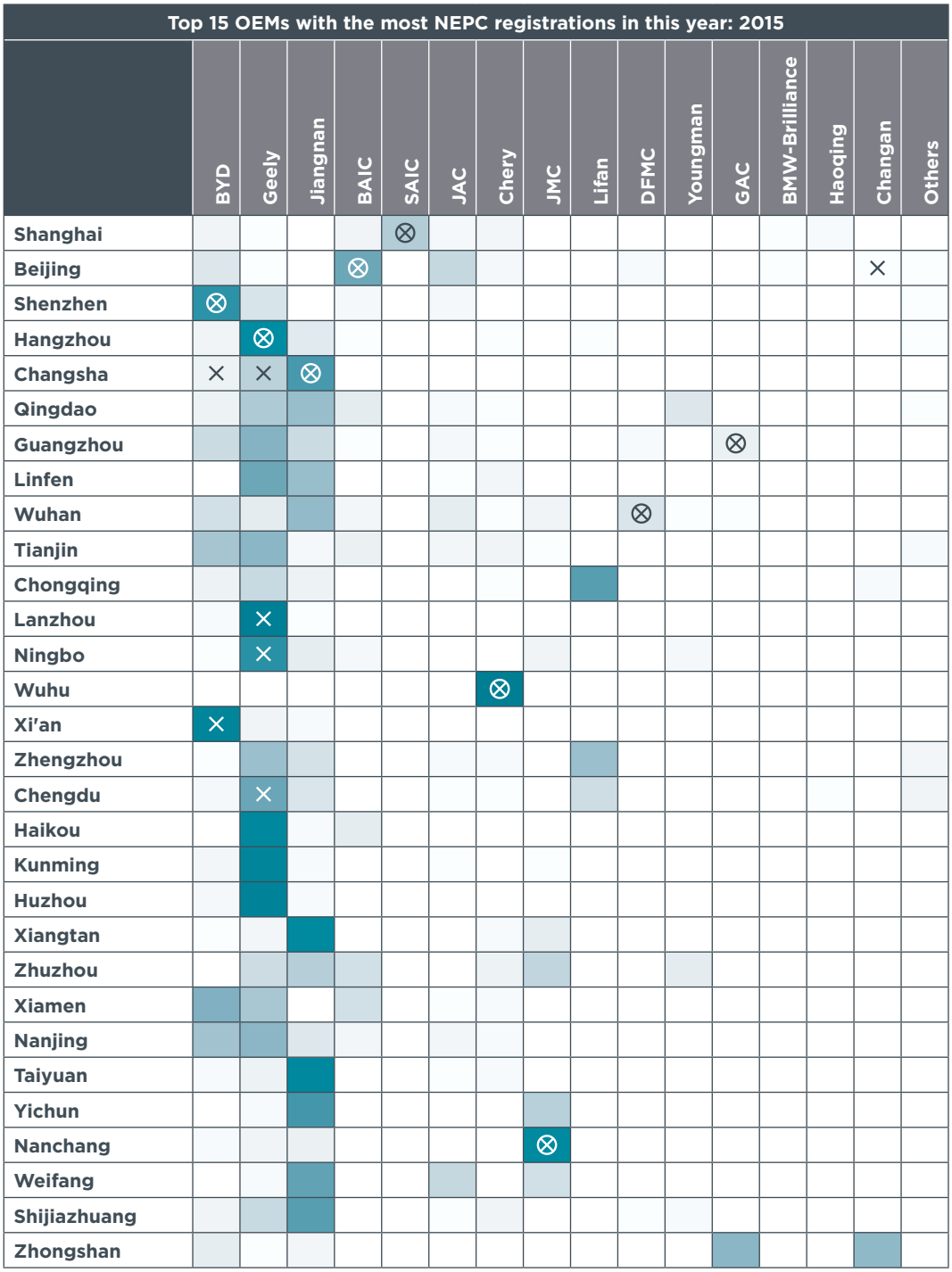
Figure 6. Geographical distribution of the 30 leading cities and their new energy passenger car technology choices, 2020.

Early in China's NEV development, local protectionism was a roadblock. Before 2015, cities tended to only promote their local brands (locally produced vehicles) and set barriers to prevent other brands from selling or excelling in their local markets. Local protectionism meant there were few players in the local NEV markets and consequently limited model choices for consumers (Shi, 2020). Figures 7 and 8 show how much this issue has been corrected from 2015 to 2020, due to central government guidance to remove local protectionism from two different angles.

Figure 7 portrays the popularity of car products from top original equipment manufacturers (OEMs) in different cities.[3] Each row represents a city market, and cells

3 In Figures 7 and 8, we treat the brands Zhidou and KanDi as Geely products. Additionally, the number of production bases in 2020 of one OEM might be greater than in 2015, due to the creation of new bases.

with shades indicate the brands have NEV sales in the city. Darker cells mean higher market penetration. In 2015, NEPC sales in all listed cities tended to concentrate on only a handful of brands. Many hotspots (the darkest cells) were in the car brands' home markets—SAIC in Shanghai, BAIC in Beijing, BYD in Shenzhen, Lifan in Chongqing, JAC in Hefei, and Geely in Hangzhou. Between 2015 and 2020, though, cities made great efforts to remove market barriers for non-local brands and ensure a level playing field for all vehicle manufacturers. Indeed, by 2020, more players had entered each city market, and fewer hotspots of local concentration were observed.



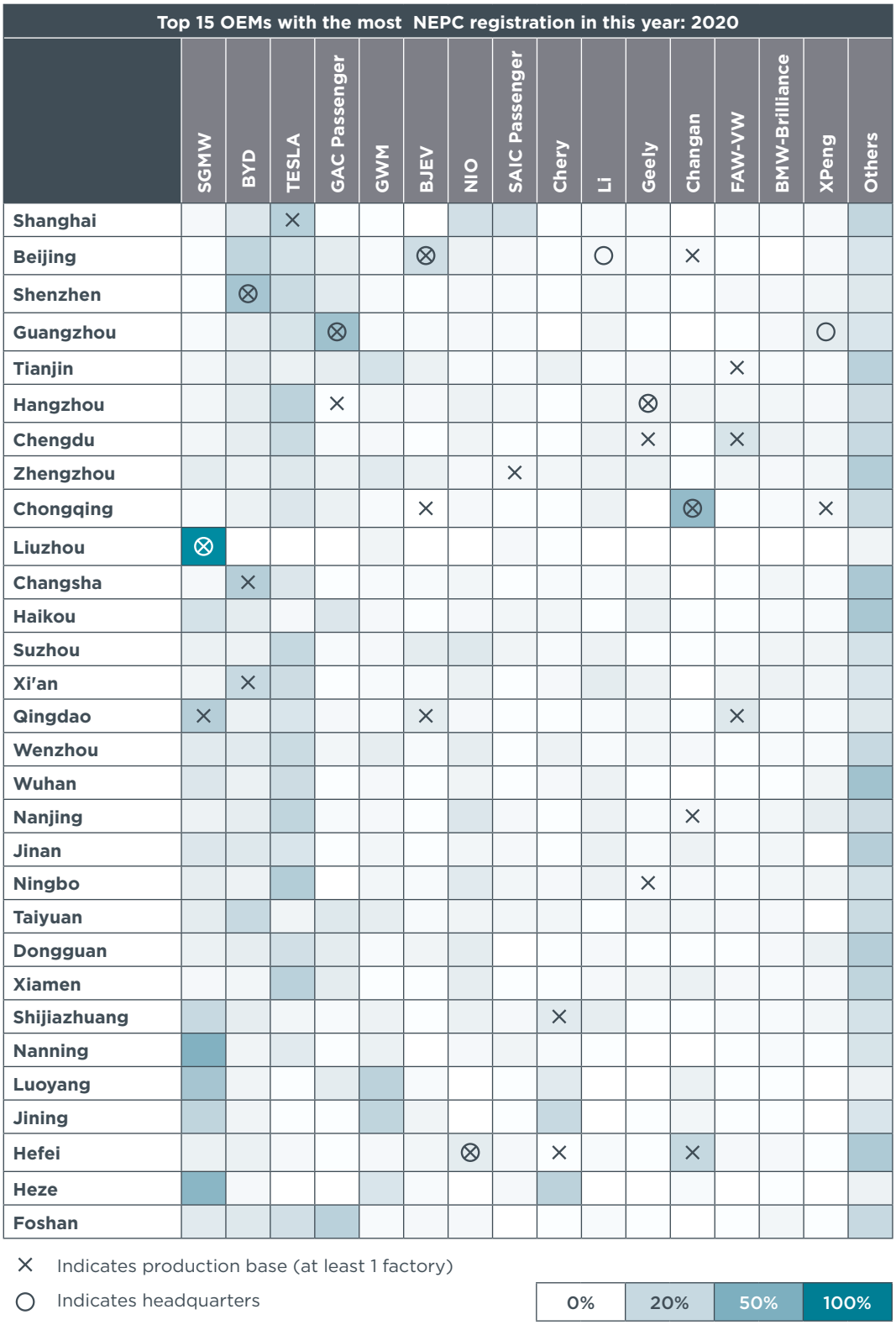
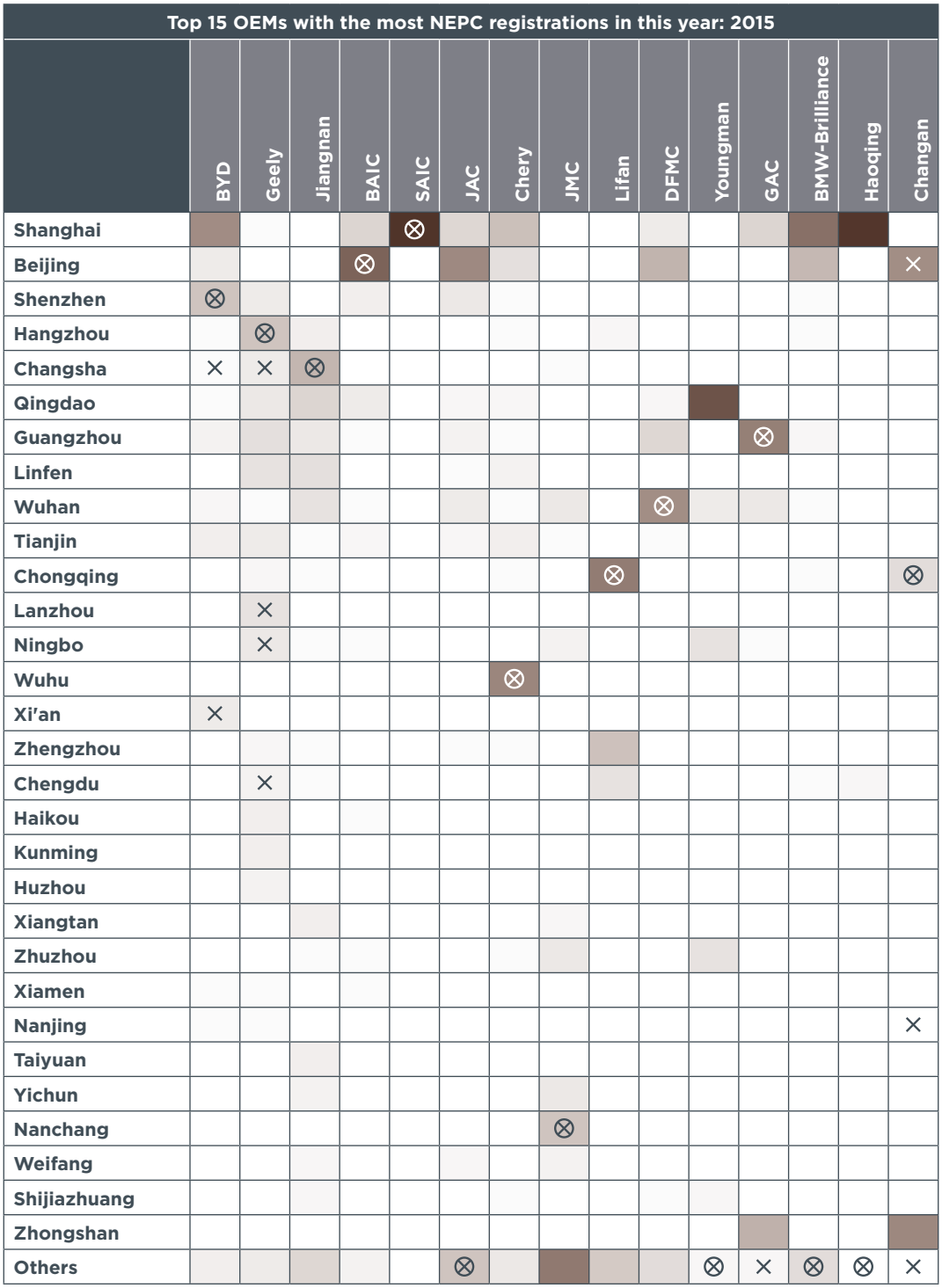


Figure 7. Brand preferences of 30 leading cities, 2015 and 2020.

*The total share added up horizontally for each city equals 100%.

Figure 8 examines where automakers rolled out their NEPC products. Each column represents an automaker, and cells with shades indicate the cities in which OEMs sold their vehicles. Darker cells mean more sales in a given city. In 2015, automakers either focused on Tier 1 cities (e.g., BYD, JAC, Brilliance BMW, Haoqing, Changan were selling in Shanghai, Beijing, and Shenzhen) or local markets where their headquarters or production base were located (BYD, Geely, Jiangnan, BAIC, SAIC, Chery, Lifan, DFMC, and GAC). Over time, though, automakers began to target more city markets and move beyond their base cities.



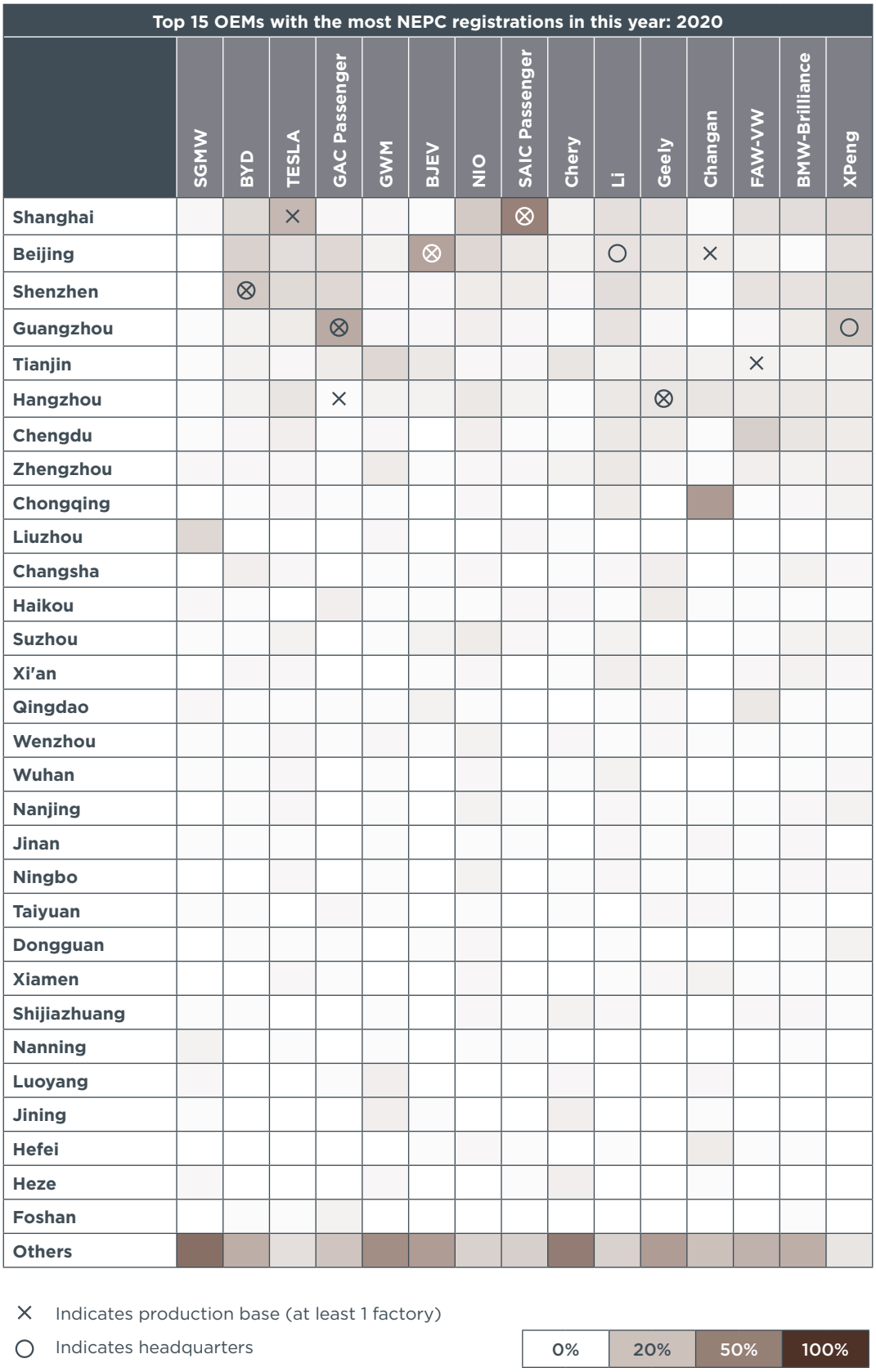


Figure 8. OEMs' deployment strategies across cities, 2015 and 2020.
*The total share added up vertically for each OEM equals 100%.

2.2. CHARACTERISTICS OF NEPC MARKETS BY CITY CLASS

China's NEPC market started in a few large cities and then spread to cities across the nation (Jin et al., 2021). The NEV development paths in the larger and smaller cities differed, and the market features are different. This section assesses market characteristics with a similar perspective and structure as in the previous section but analyzes the cities by class.

In China, cities are unofficially classified into six tiers based on population, economic output, and other business and development factors (Yu, 2021). Tier 1 cities are usually well-developed megacities with large populations, high gross regional product (GRP) and income, mostly complete transportation infrastructure, and the greatest number of business development opportunities (see Figure 9). Only four cities—Shanghai, Beijing, Shenzhen, and Guangzhou—belong to this group. The next level is New Tier 1 cities. These are large, often provincial-level cities or capital cities approaching Tier 1 cities in one or more aspects, and they are Tianjin, Chongqing, and Chengdu of Sichuan province, Hangzhou of Zhejiang province, and 11 other cities. Tier 2 cities are mainly provincial capitals or cities in Eastern China with robust economic vitality, such as Hefei of Anhui province and Xiamen of Fujian province. Tier 3 cities are typically those with a relatively strong economy and large population; examples are Sanya in Hainan province and Liuzhou in Guangxi. Tier 4 cities are mainly prefecture-level cities that are relatively medium-size in terms of population and economic strength, and these include Meizhou in Guangdong Zhuang autonomous region and Baotou in the Inner Mongolia Autonomous Region. Finally, Tier 5 cities usually have a relatively weak economy, small population, and limited transportation infrastructure and service system.

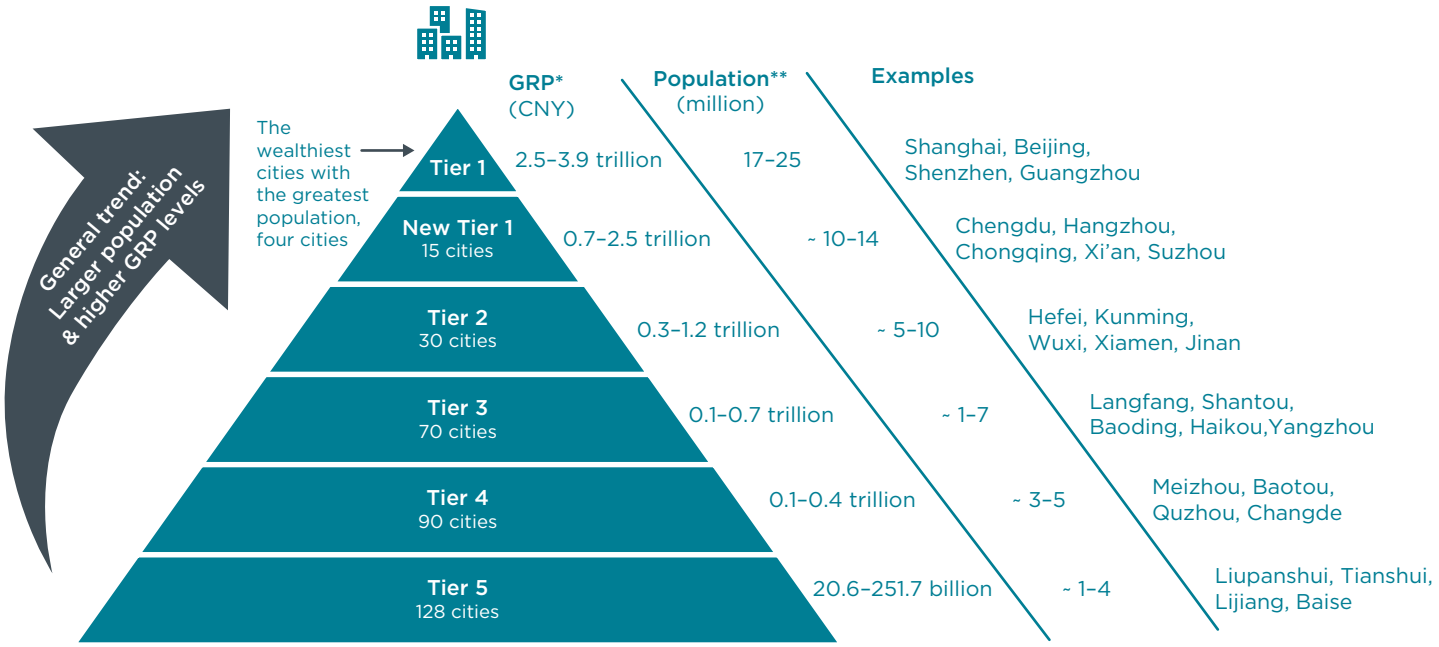


Figure 9. China's City-tier system, 2020.

* GRP refers to 2020 gross regional product of one city

** Population refers to the resident population of one city, from the 2020 census.

Figure 10 demonstrates that NEPC registrations were more evenly spread among the different city classes in 2020 than they were 5 years prior, even though Tier 1 and New Tier 1 cities remained the main subnational markets in 2020. In 2015, though, Tier 1 and New Tier 1 cities dominated the market and jointly made up nearly 80% of registrations that year. In 2020, that joint share dropped to about 58%, and the remaining city tiers together reached an approximately 42% share.

The difference in NEPC sales as city classes step down was observed in both 2015 and 2020 (right part of Figure 10). In 2015, average NEPC registrations ranged from a single digit in Tier 5 cities to over 20,000 in Tier 1 cities. In 2020, the gap between average NEPC sales in Tier 5 and Tier 1 cities was still large: a typical Tier 1 city sold 86,700 NEPCs, as opposed to an average of only 300 in Tier 5 cities. That is a nearly 286 times difference.

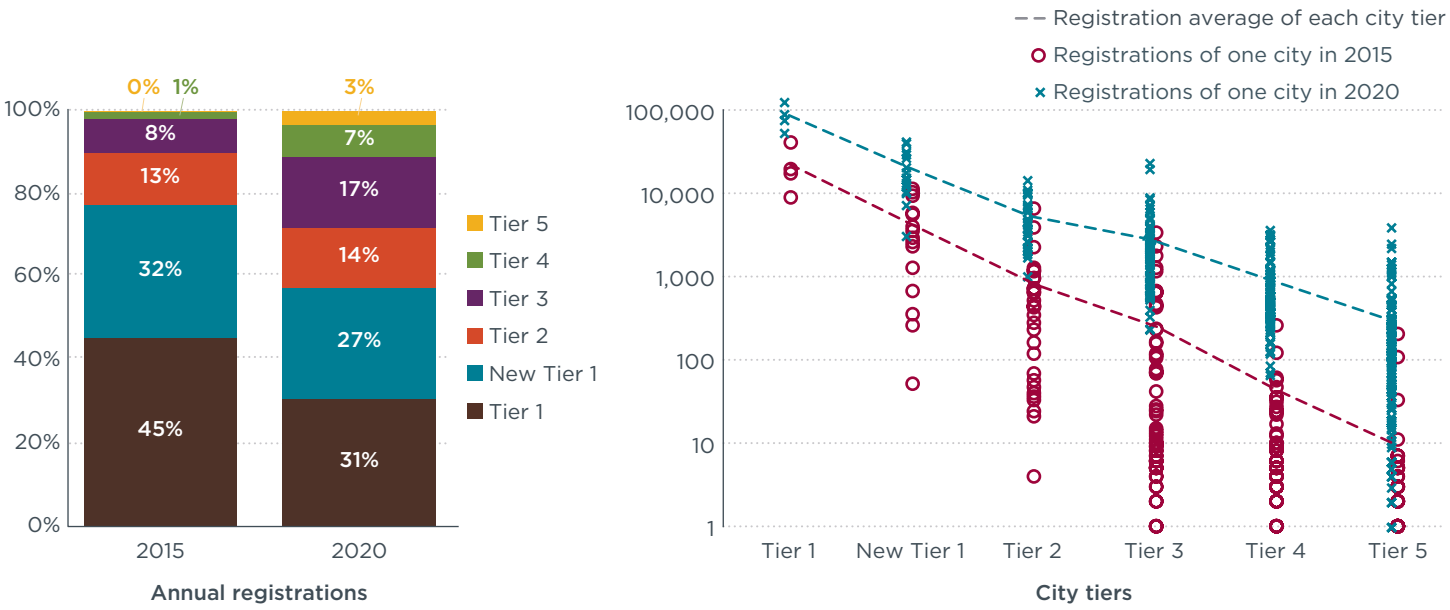


Figure 10. New energy passenger car market share (left) and market size (right) in different city tiers in China, 2015 and 2020.

Importantly, there were clear top performers in the smaller cities. For example, more than 23,000 NEPCs were registered in Tier 3 city Liuzhou in 2020, more than in any Tier 2 city and more than in many of the New Tier 1 cities. Similarly, NEPC registrations in the Tier 5 city of Puyang in 2020 were higher than the average of Tier 3 cities that year. These exemplars imply that smaller cities can perform quite well in terms of NEV deployment, and the following sections will further examine the factors leading to the strong performance of top cities in the different classes.

Figures 11, 12, and 13 replicate the analysis regarding vehicle ownership, segmentation distribution, and technological features as in the previous section but by city class. As shown, there were more commercial-use NEPCs, namely taxis and cars used for rental or ride-hailing purposes, in 2020 than in 2015 in all city classes except in Tier 1. Differences in the average vehicle electric range and battery capacity among various city classes were not evident in 2015. Nonetheless, consumer preference for larger and longer-range NEPCs in Tier 1–2 cities became apparent 5 years later. In 2020, larger-size car categories (B, C, SUVs, and MPVs) dominated the Tier 1 and New Tier 1 city markets. Specifically, market shares of new energy SUVs and MPVs in Tier 1 and New Tier 1 cities were 33% and 28%, respectively. In contrast, consumers in Tier 3–5 cities distinctly favored mini NEPCs (A00 category), and these vehicles composed 53%–57% of their local NEPC markets in 2020. The average electric range of BEVs in Tier 1 cities in 2020 was 450 km, and that declined to about 400 km in New Tier 1 cities, and then further down to about 370 km in Tier 2 cities; finally, for the smallest city groups, the average stayed around 280–300 km in 2020. A similar pattern was observed for battery capacity.

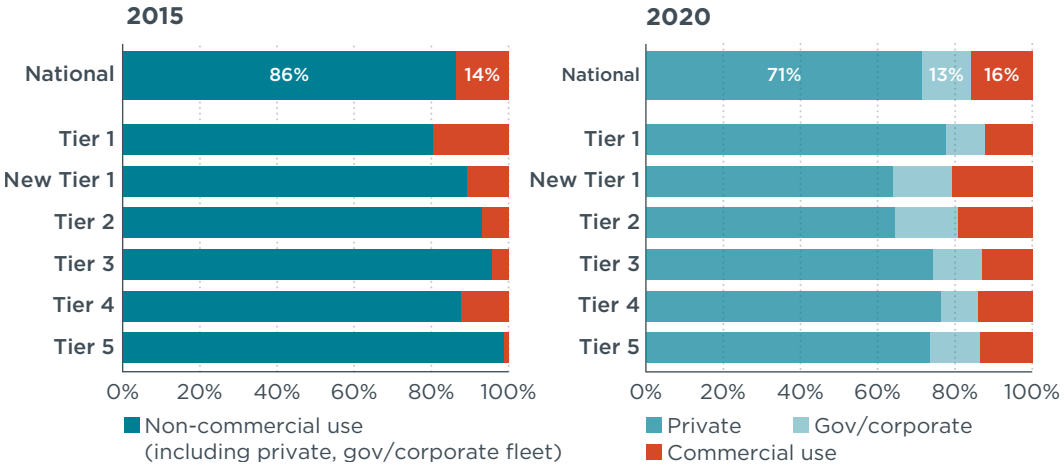


Figure 11. Composition of local new energy passenger car markets by ownership and usage type across the city classes, 2015 and 2020.

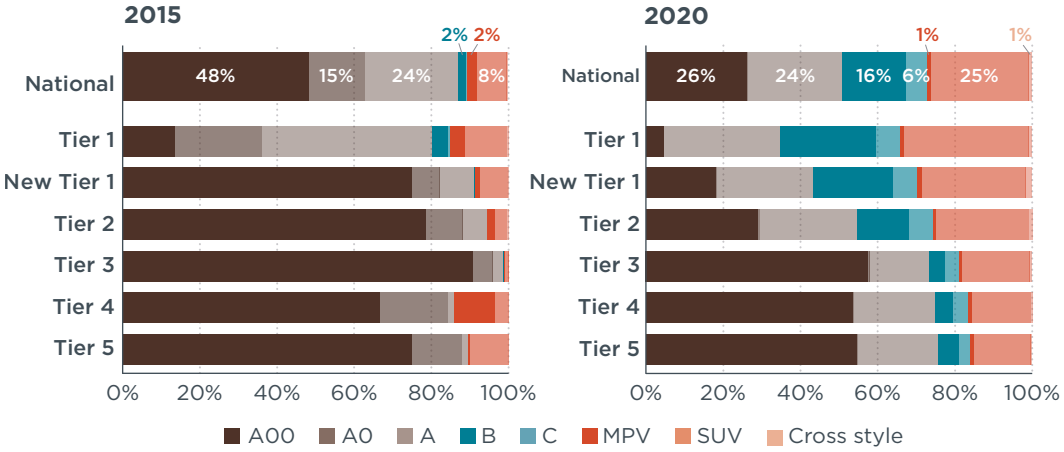


Figure 12. Composition of local new energy passenger car markets by vehicle segment across the city classes, 2015 and 2020.

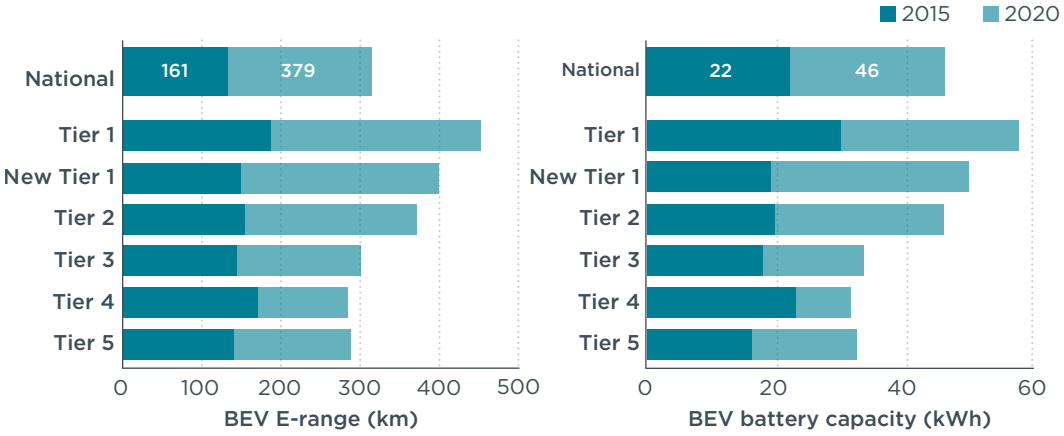


Figure 13. Average BEV electric range and battery capacity across the city classes, 2015 and 2020.

The above market characteristics can be primarily explained by the NEPC model preference across cities (Figure 14). Though the Tesla Model 3 snatched the national-level sales crown for NEPCs in 2020, a different model was the winner at certain city-class levels; the Model 3 was the best-selling model in Tier 1 and New Tier 1 cities, but the Wuling Hongguang Mini EV was the top in all the other tiers. The Wuling Hongguang Mini EV costs only CNY 30,000 – CNY 40,000 (subsidies are not considered) and offers a 120 – 170 km electric range and a very compact hatchback body. Meanwhile, the most popular vehicle models in individual cities were quite diverse and influenced by more factors. As shown in Figure 14, the best-selling BEV

models in Guangzhou, Chongqing, and Liuzhou were the Trumpchi AION.S, EADO, and Baojun E200, respectively—all made by local automakers. These models took up over 30% of their local markets in 2020.

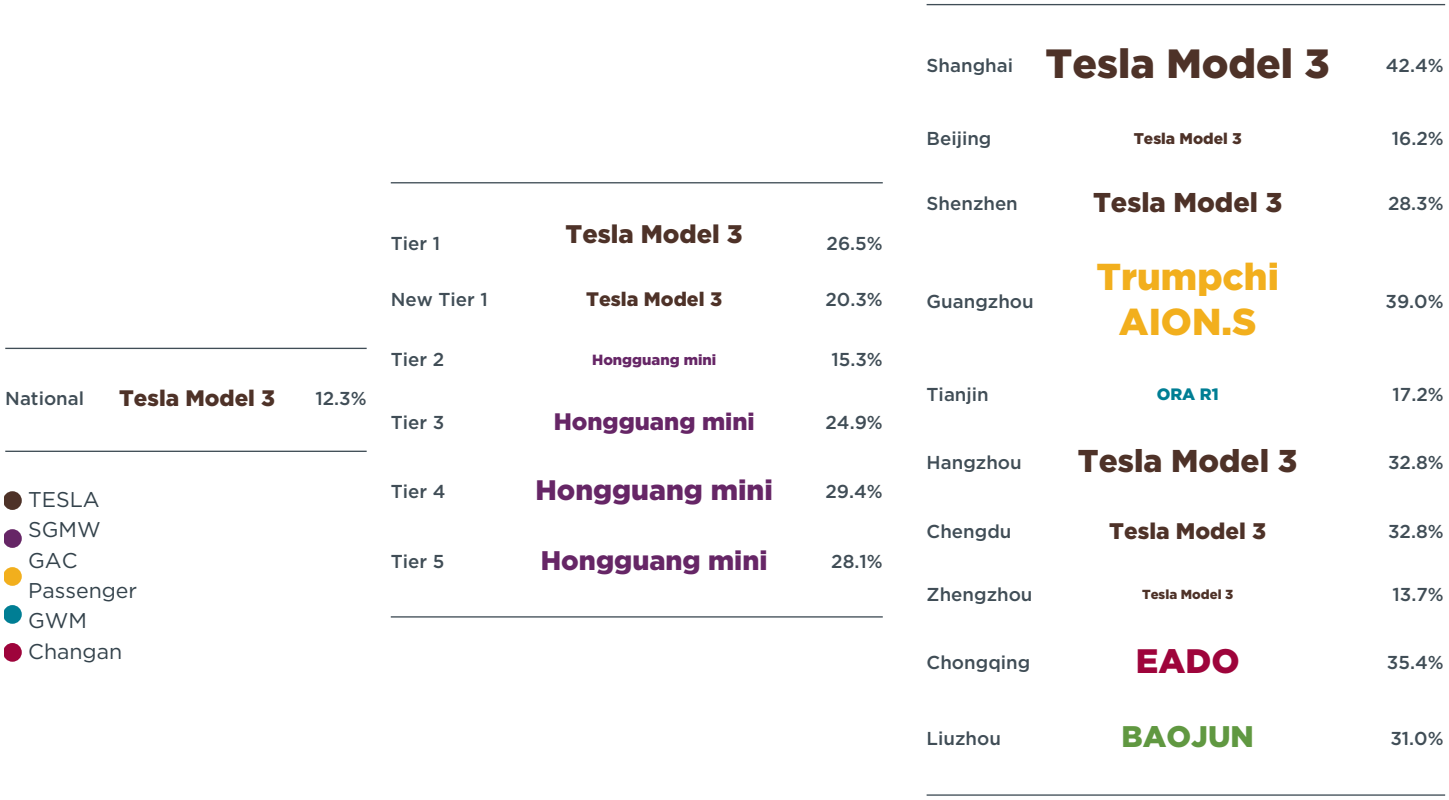


Figure 14. The 2020 most popular battery-electric passenger car models and their market penetrations at national and sub-national levels.

To conclude this subsection, we summarize our NEPC market analysis at the city and city-class levels into the following five features:

- Tier 1 and New Tier 1 cities remained the top players in the NEPC market in 2020, but smaller cities narrowed the gap between 2015 and 2020.
- The private NEPC market became more mature, and sales of commercial-use vehicles also grew substantially.
- Larger-size, longer-range NEPCs dominated in large cities, while consumers in smaller cities favored mini-size, shorter-range, more affordable models.
- NEPC deployment concentrated in Eastern, Central, and Southern China, and BEVs were predominant.
- Policies to reduce local protectionism proved effective, as NEPC market diversity significantly increased during the 5 years analyzed.

2.3. LEADING NEPC MARKETS IN EACH CITY CLASS

This section identifies the most successful local NEPC markets in each city class and then provides a more granular analysis of their characteristics, including select examples, to consider factors that likely drove their success. Specifically, we analyzed the top five cities of each tier based on their rank in terms of NEPC market share in 2020.[4] Figure 15 provides a snapshot of these top local markets.

4 Tier 1 city section is one exception, as there are only four Tier 1 cities in China. Additionally, we used NEPC market penetration instead of sales volume to normalize the difference between big and small vehicle markets.

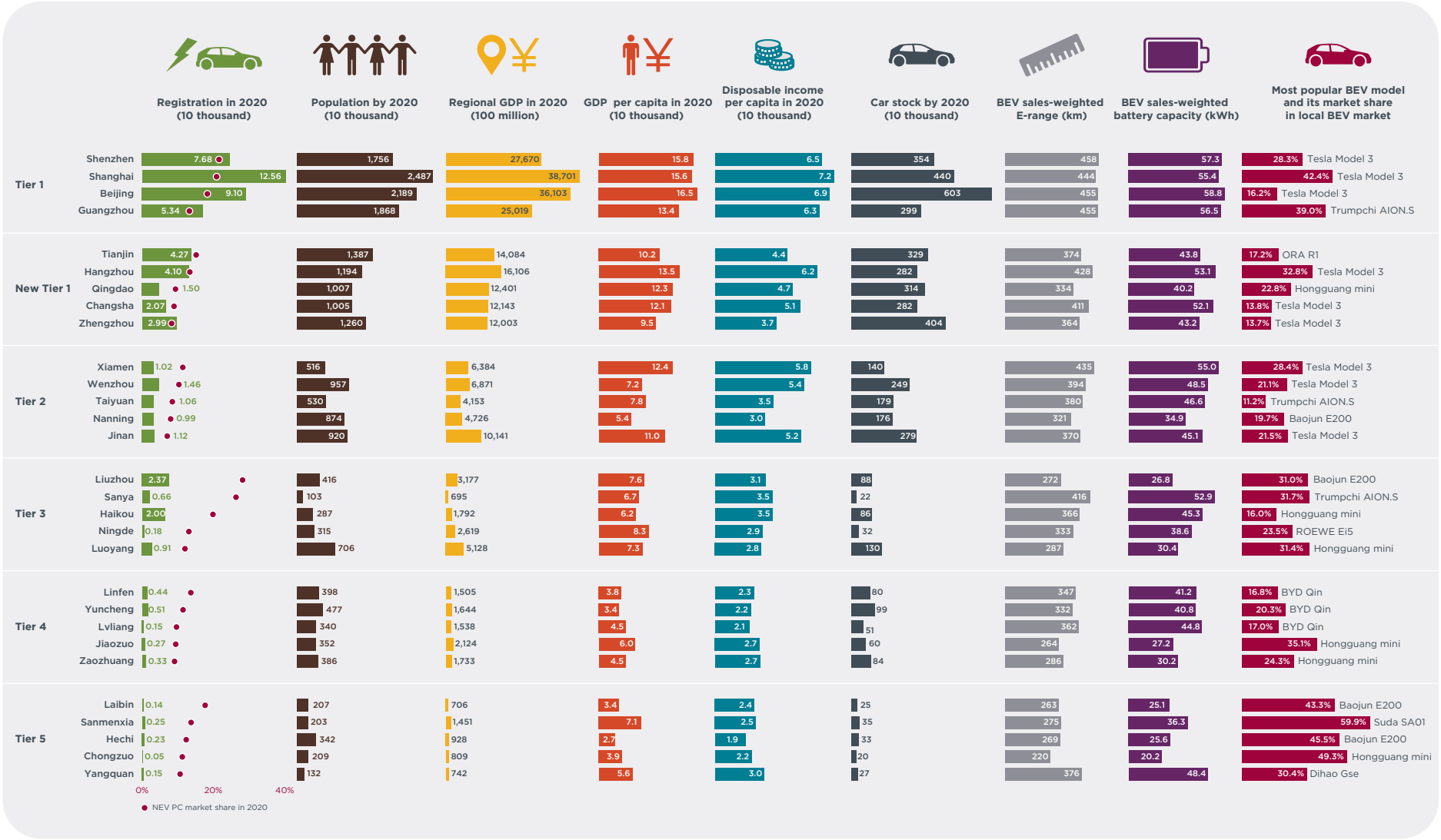


Figure 15. Top five cities in each city class with the highest levels of new energy passenger car market penetration in 2020 and their absolute registration volumes and other relevant characteristics.

2.3.1. Tier 1 cities (megacities)

In 2020, approximately 347,000, or 31% of all new NEPCs registered in China, were from Tier 1 cities. NEPC registrations in these four cities ranged from 53,000 in Guangzhou on the low end to 126,000 in Shanghai on the high end, and NEPC market penetration ranged from 12.2% in Guangzhou on the low end to 21.5% in Shenzhen on the high end.

Tier 1 cities are the wealthiest in China, especially when considering per capita disposable income. Consumers in those cities preferred higher-end BEV models like the Tesla Model 3 and the Trumpchi AION.S, both of which offer more than 400 km electric range and are powered by over 50 kWh battery packs.

Policies seemed to have played a major role in market development. All Tier 1 cities were enlisted in and supported by the Ten Cities, Thousand Vehicles pilot program. After that, the cities set clear goals for NEV deployment and charging infrastructure buildout, and deployed a wide range of promotional incentives. Direct monetary incentives have included city-level subsidies for vehicle use in Shenzhen and Guangzhou, construction of charging infrastructure in all Tier 1 cities, charging fee subsidy in Shanghai, and waived or reduced parking fees in Shenzhen. Yet a very influential policy instrument for NEV uptake in Tier 1 cities was a nonfiscal measure: the registration or licensing incentive given to NEVs. This put an annual quota on new car registrations in the cities to combat congestion and traffic-related pollution, and a larger share of the quota was assigned to NEVs than to conventionally powered cars. Such privilege took the form of a license plate number lottery in Beijing and auction in Shanghai; in Guangzhou and Shenzhen, it was a hybrid of the two. However structured, this policy makes it easier for consumers to register an NEPC than a combustion engine vehicle. Other indirect incentives offered include road access privileges for NEVs on weekdays in Beijing.

2.3.2. New Tier 1 cities

In 2020, approximately 300,000, or 27% of all new NEPCs registered in China, were from New Tier 1 cities. Tianjin, Hangzhou, and Qingdao (Shandong province), Changsha (Hunan province), and Zhengzhou (Henan province) were the top five among the 15 cities in this class. NEPC sales in these top five cities ranged from 15,000 in Qingdao on the low end to 43,000 in Tianjin on the high end, and NEPC market shares ranged from 6.6% in Zhengzhou on the low end to 14.3% in Tianjin on the high end.

The average per capita disposable income in New Tier 1 cities in 2020 was about 20% lower than it was in Tier 1 cities, and that likely partially explains the lower average NEPC share and the features of the NEV models popular in these markets. In addition, the average electric range and battery capacity of BEVs in New Tier 1 cities was 71 km and 11 kWh less, respectively, than in Tier 1 cities. The most popular car models in these five cities were the Tesla Model 3, Wuling Hongguang's Mini EV, and Ora R1 by Great Wall Motors (GWM). The Ora R1 is a mini-size BEV model with 300 – 400 km of range and it costs about CNY 70,000 – CNY 80,000 to purchase (subsidies are not considered). The high sales in Tianjin in 2020 were mainly attributable to Ora's successful and innovative consumer campaigns, including live commerce and offline auto show in malls, efforts to expedite vehicle production and delivery, and efforts to enhance customer service (Autohome, 2021).

The five leading New Tier 1 cities are also participants in the Ten Cities, Thousand Vehicles pilot program. Some of them have followed the best practices of Tier 1 cities. For instance, Tianjin and Hangzhou offered a "direct-registration" license plate privilege to NEPCs while using a lottery-plus-auction system for registering ICE cars (Tianjin Passenger Vehicle Total Volume Control Service Center, 2019; Hangzhou Municipal Government, 2017). In addition, Tianjin, Zhengzhou, and Hangzhou had

traffic control measures, and the former two cities, exempted NEPCs from the restriction (Tianjin Municipal Public Security Bureau, 2020; Zhengzhou Public Security Bureau, 2020; Hangzhou Municipal Government, 2020a). Two cities provided subsidies for consumers or charging facility owners in 2020 in different ways. Tianjin offered a CNY 2,000 per car charging voucher for new NEPCs registered (Tianjin Municipal Government, 2020) and Hangzhou provided a 30% subsidy for public or shared charging facilities' construction investment and a CNY 600 per charger charging subsidy for individual consumers (Hangzhou Municipal Government, 2020b). Consumers in two cities benefited from local car sales promotion policies: Changsha offered a 3% (not exceeding CNY 3,000) purchase subsidy per car, and Zhengzhou offered a CNY 5,000 subsidy per car (Changsha Evening News, 2020; Zhengzhou Development and Reform Commission, 2020).

2.3.3. Tier 2 cities

In 2020, approximately 160,000, or 14% of all new NEPCs registered in China, were from Tier 2 cities. Xiamen (Fujian province), Wenzhou (Zhejiang), Taiyuan (Shanxi), Nanning (Guangxi), and Jinan (Shandong) were the top five local markets among 30 cities in this class. NEPC sales in these cities ranged narrowly from 9,900 in Nanning on the low end to 14,600 in Wenzhou on the high end, with an average of 11,300 in 2020,

BOX 1. GUANGXI MODE

Nanning and a few other cities in Guangxi Zhuang autonomous region (hereafter Guangxi) followed a similar NEV development path, previously known as Liuzhou mode, and today it has evolved into Guangxi mode. It essentially endeavors to duplicate and expand upon Liuzhou's NEV success, and it is motivated by the region's ambition to build a local NEV industry hub (Jiang, 2019). Guangxi mode is focused on promoting the locally produced Baojun E series (primarily the E100 and E200); these are two-seater mini electric cars with a Smart car-like appearance and a price tag of about CNY 50,000.

The success of Guangxi mode is primarily owing to manufacturer SGMW's precise market assessment and consumer targeting. The Baojun models were designed specifically for the niche market of these smaller cities. The 100–200 km range perfectly fits local consumers' most common driving needs, including daily commute, school drop-off and pick-up, and grocery store visits, and the price is highly affordable. To test the water, Wuling also carried out a free test drive campaign in Liuzhou over 10 months in 2017 that engaged more than 15,000 residents to take the E100 for a spin (Cui & He, 2019a). This campaign not only provided the automaker with feedback from thousands with which to improve the car's design, but it also brought the company about 10,000 orders.

After the vehicle models proved to be attractive to consumers, the government focused on solving the pain points around charging and parking. Thanks to the mini size of the cars, they can fit in urban sidewalks and many otherwise unused corner spaces in the city. The Liuzhou city government motivated its citizens with awards to find all such usable spaces and then designated them as NEV parking lots (Sohu News, 2017a). Additionally, upon discovering that standard public charging infrastructure would not be economically viable for the city, Wuling upgraded their models to be able to charge via household sockets (Li, 2019) and the local government offered subsidies for installing these charging sockets in public parking lots and for retrofitting the infrastructure in older residential areas (Liuzhou Development and Reform Commission, 2020a). Other incentives included reduced parking fees, allowing NEVs to drive in dedicated bus lanes during rush hours, and streamlining and expediting vehicle registration and charger construction approval processes (Yang & Wu, 2018; Zheng, 2017; Liuzhou Development and Reform Commission, 2020b).

Now the Guangxi mode is supported by the regional government and enclosed in the region's industrial development plan (Development and Reform Commission of Guangxi Zhuang Autonomous Region, 2019). The region is continuing to upgrade the NEV industry in Liuzhou by building a complete supply chain, including product research and development, manufacturing, and post-sale services, and focusing on manufacturing new energy buses, components, and charging infrastructure in Nanning.

less than half of the average of the top five in the New Tier 1 class. NEPC market shares ranged from 5.3% in Jinan on the low end to 10.1% in Xiamen on the high end.

Despite a smaller population and lower overall GRP, average per-capita disposable income in Tier 2 cities was nearly the same as it was in New Tier 1 cities. Vehicle model preference and features in Tier 2 cities were similar to those in New Tier 1 cities, as well, with one exception. The Baojun E200 by SAIC-GM-Wuling (SGMW) was the best-seller in Nanning; the city is adjacent to Liuzhou, where the car manufacturer's headquarters is located, and is part of the new *Guangxi mode* of promoting NEVs.

Taiyuan benefited from the national government's "NEVs go to the countryside" campaign[5] and the local government's supportive policies to new energy ride-hailing car fleets. The city once had a goal of replacing all ICE vehicles in ride-hailing fleets by 2020 and banning the use of traditional fuel ride-hailing fleets from 2021 (Wangyi News, 2020).

2.3.4. Tier 3 cities

In 2020, approximately 194,000, or 17% of all new NEPCs registered in China, were from Tier 3 cities. Liuzhou (Guangxi), Sanya (Hainan), Haikou (Hainan), Ningde (Fujian), and Luoyang (Henan) were the top five local markets among 70 cities in this class. NEPC sales in these cities ranged from 1,800 in Ningde on the low end to 23,700 in Liuzhou on the high end, with an average of 12,230 in 2020, higher than half of the average of the top five in Tier 2. NEPC market shares in Tier 3 cities ranged from 10.8% in Luoyang on the low end to 28.9% in Liuzhou on the high end.

The average per capita disposable income in the five leading Tier 3 cities in 2020 was just over CNY 30,000, a third less than in Tier 2 cities. Regardless, a few Tier 3 cities had some of the nation's most outstanding performances in NEPC deployment in 2020.

In 2020, Sanya and Haikou of Hainan province had high NEPC market shares of 27% and 20%, respectively, and this was driven by Hainan's ambitious Clean-Energy Vehicle Roadmap (hereafter "the Roadmap"), which included targets of 40% electric share of new private cars, 100% clean taxi fleets (NEVs and natural gas vehicles qualify), and 100% new energy car-sharing fleets in 2020 (Cui & He, 2019b). The pioneering provincial plan was part of the efforts to create first-rate environmental conditions and a green image for the province to match the world-class free trade port under construction. Because most passenger car registrations were in Sanya and Haikou, these two cities were the primary sites to implement the Roadmap. Promotional actions for NEPCs in these cities included government, corporate, and commercial fleet procurement requirements, local purchase subsidies (CNY 10,000 per car, effective only in 2020), licensing and road access privileges, and subsidies for building and operating charging facilities (Li & Cui, 2022).

Ningde is the home base of CATL (the company's Chinese name means Ningde era), the world's largest maker of NEV batteries, and the city's 2020 NEPC market share was 12%. The rise of CATL made Ningde a major town in China's lithium battery industry and helped form an agglomeration between it and other vital players upstream and downstream in the NEV industry supply chain, including automotive giants like the SAIC motor Group (Sohu News, 2020). Ningde expanded its NEV market by leveraging its industrial advantages and this included multiple varieties of government initiatives to attract investment, financial support for technology upgrades in firms along the

5 NEVs Go to the Countryside was a joint effort between the central and local governments and car manufacturers to revive domestic automotive consumption and industry during the economic downturn that started in 2020. The goal was to encourage consumers in smaller cities and rural regions to buy more NEVs. The first round of the campaign took place in five major cities, Taiyuan, Tsingdao, Haikou, Kunming, and Chengdu, and their surrounding small cities towns: http://scyxs.mofcom.gov.cn/article/h/202007/20200702983138.shtml

NEV supply chain, and discounted interest rates for qualified small- and medium-size enterprises in the NEV industry. Other NEV promotion policies in Ningde were similar to those in cities mentioned before, such as setting clear goals for NEV industry development, NEV deployment, and charging infrastructure; offering the first 2 hours of parking for NEVs for free; a lower rate for the electricity used for charging (Zhang, 2020; Ningde Municipal Government, 2020a); and a one-time subsidy of CNY 4,000 for charging (Ningde Municipal Government, 2020b).

2.3.5. Smaller cities and towns

In 2020, approximately 121,000, or 10% of all new NEPCs registered in China, were from Tier 4 or Tier 5 cities. Linfen (Shanxi province), Yuncheng (Shanxi), Lvliang (Shanxi), Jiaozuo (Henan), and Zaozhuang (Shandong) were the five leading cities among 90 Tier 4 cities and Laibin (Guangxi), Sanmenxia (Henan), Hechi (Guangxi), Chongzuo (Guangxi), and Yangquan (Shanxi) were the leaders of the 128 Tier 5 cities. These smaller cities were also minor NEV markets in terms of absolute sales, which were under 10,000 in all cities in 2020. However, their NEV market shares were remarkably high, ranging from 7.5% in Zaozhuang on the low end to 17.1% in Laibin on the high end; the average was 11%. Small and economical car models like the Hongguang Mini and Baojun E-series prevailed in these markets, leading to lower fleet-average electric range (299 km) and battery capacity (34 kWh) than in the other city tiers.

These thriving small NEV city markets can be explained mainly by the diffusion effect of bigger cities in the same region. Specifically, Laibin, Hechi, and Chongzuo were part of the Guangxi mode (Tang, 2019; Tycar, 2019) described in the previous section. Additionally, Linfen, Yuncheng, Lvliang, and Yangquan imitated the NEV development strategies in Taiyuan (Li, 2020; Chai, 2020; He & Xue, 2020; Feng, 2020), the capital city of the province in which they are all located.

3. DEVELOPMENT OF NEW ENERGY COMMERCIAL VEHICLES IN CHINESE CITIES

This chapter first presents observed trends in the market for new energy commercial vehicles (NECVs), and then dives into the top-performing city markets by major vehicle categories. The intent is to analyze how macroeconomic factors and policy drove the development of NECVs in cities from a bird's-eye view. In the context of this study, commercial vehicle refers to straight truck, dump truck, tractor truck, city bus, coach, urban logistics vehicle,[6] and other unspecified buses and utility vehicles[7] (see Table 1).

Table 1. The major new energy commercial vehicle categories in China

Trucks			Buses			Utility vehicles	
Straight truck	Dump truck	Tractor truck	City bus	Coach	Other unspecified buses	Urban logistics vehicle	Other utility vehicles
							

3.1. OVERALL MARKET TRENDS

China's NECV market grew strongly after 2014, the year that new registrations surpassed the milestone of 10,000 units. The market then grew by more than 10 times between 2014 and 2018 and reached nearly 200,000 units newly registered in 2018. It then declined to about 117,000 units newly registered in 2020. The top 20 city markets with the largest cumulative NECV registrations from 2012 through 2020 were led by Shenzhen, Beijing, Chengdu, Guangzhou, and Shanghai, and they constituted over half of the entire market in 2020 (Figure 16).

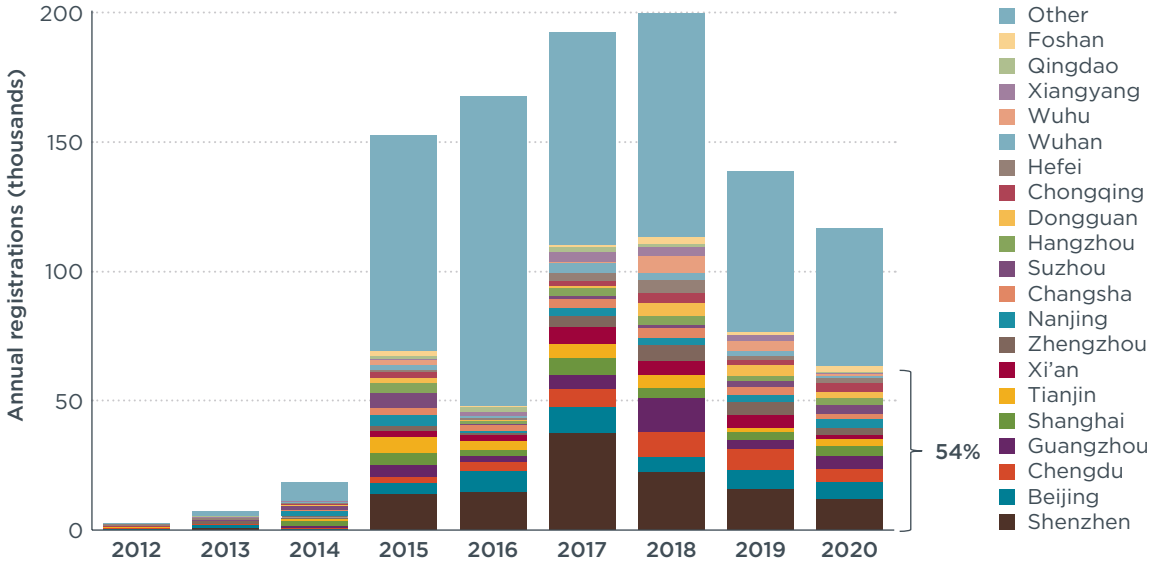


Figure 16. Registration of new energy commercial vehicles in top cities, 2012–2020.

6 According to the national standard, *Technical requirements for lectotype of urban logistics distribution vehicles* (GB/T 29912 -2013), urban logistics vehicles include two types, cargo van and close van. Therefore, we regard new energy commercial vehicles with names of these two types, as urban logistics vehicles in our analysis.

7 Utility vehicles, also called special purpose vehicles in China, referring to a set of functional vehicles such as refrigerated trucks, post office vehicles, engineering trucks, and sanitation vehicles, etc.

Figure 17 focuses on 2020 new registrations only, and the top 20 cities with the largest number that year each had at least 1,000 registrations. Together they made up nearly 60% of the national total in 2020. Registrations of NECVs in these cities ranged from 1,000 to over 12,000, with NECV shares between 2.4% and 12.8% of the commercial vehicle market; the average was around 6%. Shenzhen ranked first in both NECV registrations and market share in 2020.

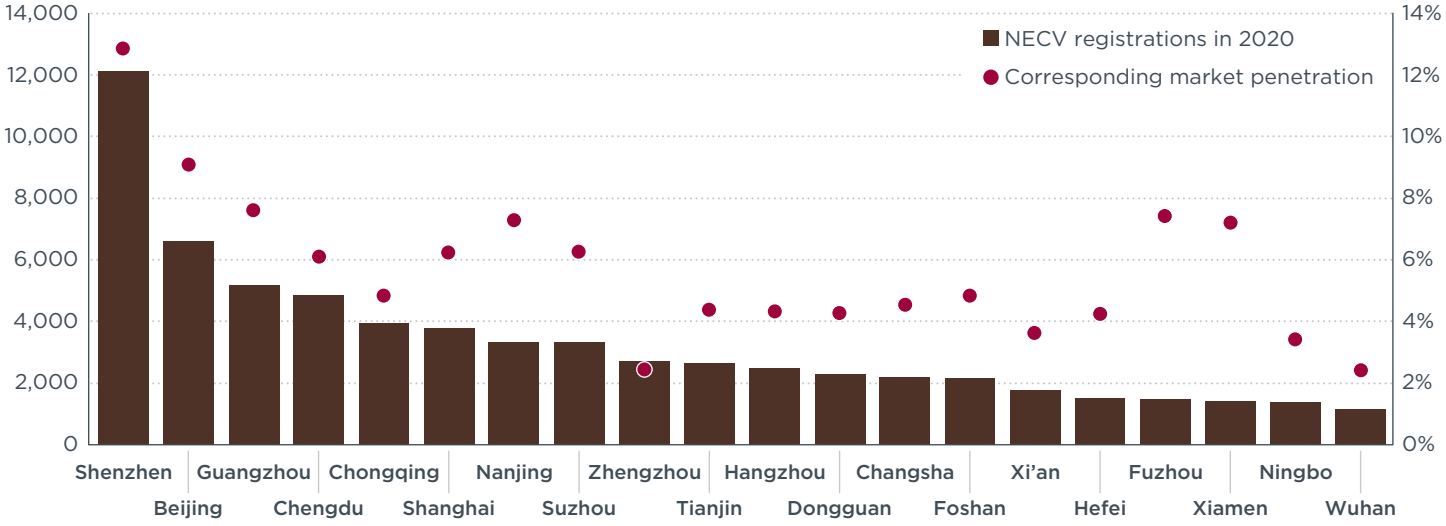


Figure 17. New energy commercial vehicle registration and market penetration in leading cities, 2020.

Before 2014, the NECV market was primarily driven by vehicles that carry passengers, mostly city buses. Since then, however, other types of commercial vehicles have begun to gain market traction, especially urban logistics vehicles and other utility vehicles including refrigerated trucks, post office vehicles, engineering trucks, and sanitation vehicles that surged after 2017. The largest and heaviest vehicle categories, dump trucks and tractor trucks, began to emerge in the market in 2018 (Figure 18).

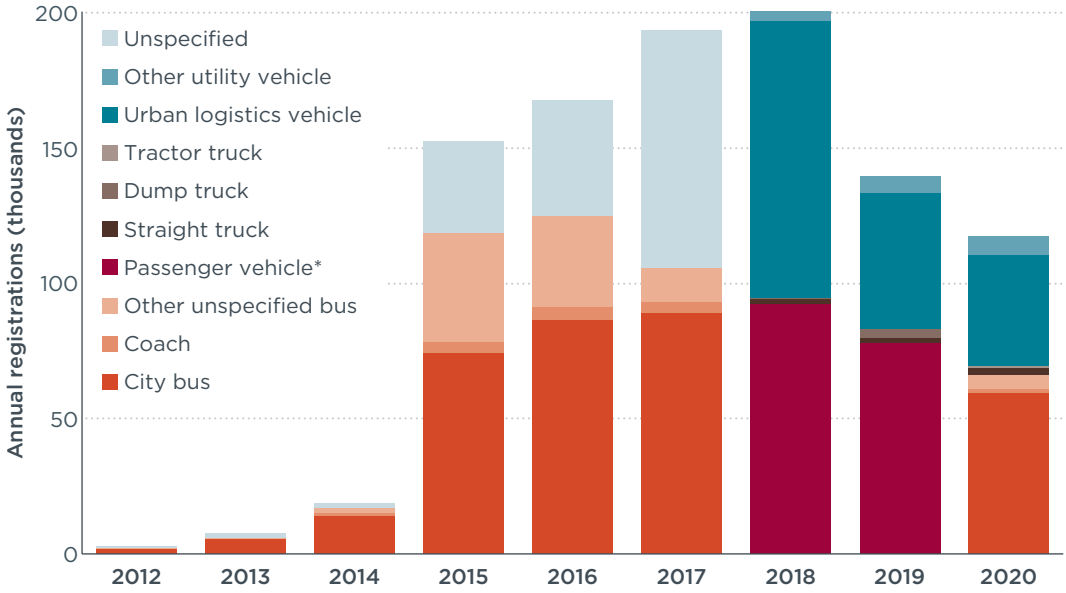


Figure 18. Registration of new energy commercial vehicles by broad category, 2012–2020.

*Passenger vehicle includes city bus, coach, and other unspecified bus; available data did not allow us to differentiate between city bus and coach in 2018 and 2019.

Like the passenger car market, NECV sales were significantly higher in larger and more affluent cities than in smaller, less-developed ones. A typical Tier 1 city in 2020 deployed over 6,000 NECVs, which was about 10 times the average in Tier 3 cities, and 100 times more than an average Tier 5 city did (Figure 19). Different from the passenger car market, NECV sales were more evenly distributed among the various city classes in 2015 than in 2020.

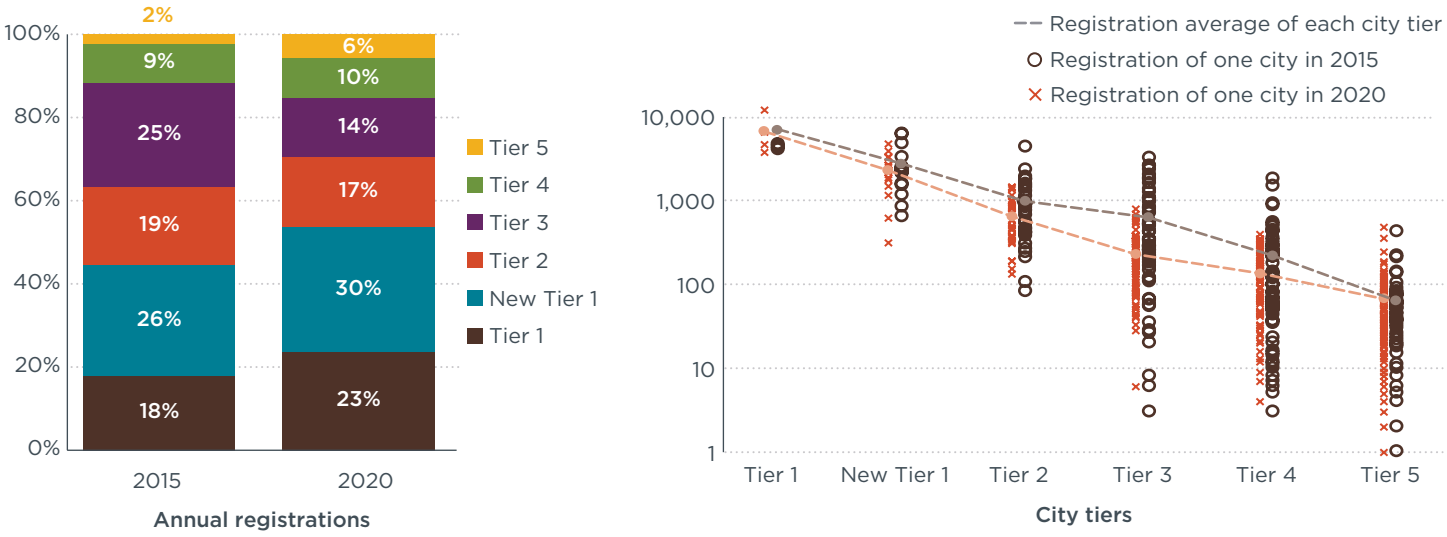


Figure 19. New energy commercial vehicle market share (left) and market size (right) in different city tiers in China, 2015 and 2020.

Figure 20 plots the spatial distribution of new registrations of different types of NECVs in China in 2020. Guangdong province was the largest subnational market in 2020, deploying nearly 26,000 NECVs that year, more than one-fifth of the national market. For passenger NECVs, registrations were spread across the nation, with most occurring in densely populated areas of Southern, Eastern, Central, and Northern China. Urban logistics vehicles were predominantly sold in Guangdong, Sichuan, Jiangsu, and a handful of central provinces; this is reflective of the thriving retail businesses and urban logistics in these regions. Heavier dump trucks and tractor trucks, in contrast, were mostly used in Northern China, where the transportation demands were high for heavy bulk goods such as coal and construction materials.

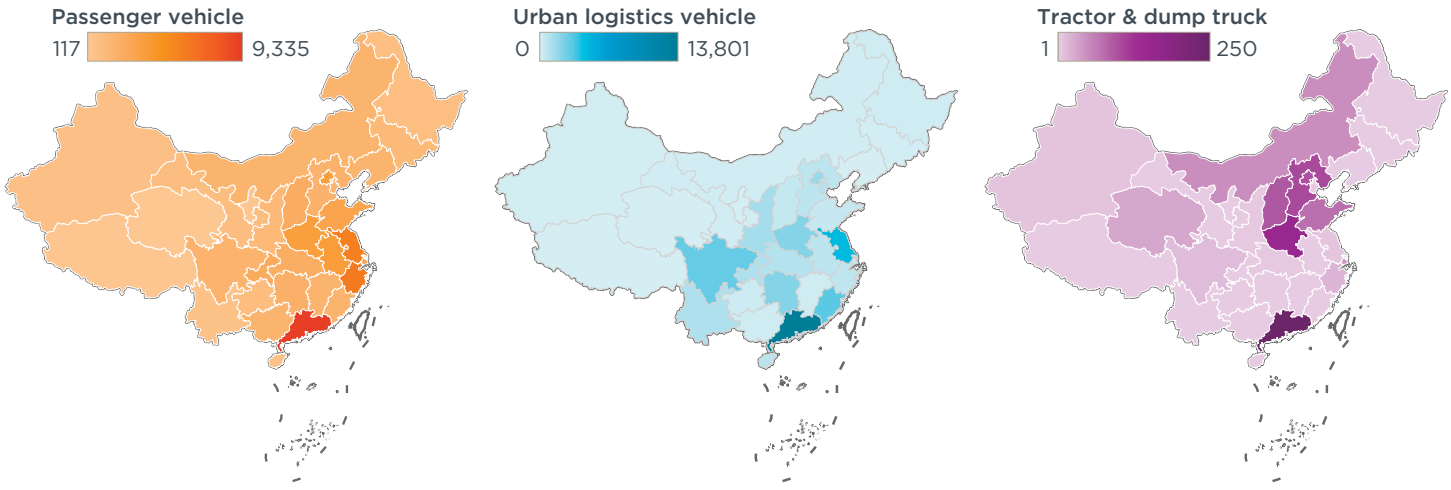


Figure 20. Spatial distribution of registrations of commercial vehicles that carry passengers, urban logistics vehicles, and tractor and dump trucks, 2020.

Figure 21 examines the relationship between the average annual freight tonnage transported on road and the freight capacity of new energy road trucks deployed in 2020 in 31 inland provincial-level jurisdictions.[8] Unfortunately, data constraints prevented us from analyzing new energy road truck inventory, which is more reflective of their freight transportation capacity.

Guangdong province, one of China's most prosperous regions and most successful export and trade hubs, was home to the second largest amount of tonnage transported via road freight. The province outperformed the rest of the nation by a wide margin in deploying new energy road trucks. Two other relatively freight-intensive provinces, Sichuan and Jiangsu, were also relatively advanced in their new energy truck markets, with annual sales surpassing 4,000 units and 5,000 tonnes of road freight capacity from new energy road trucks. However, many other regions with substantial freight activities, including Shandong, Anhui, Hebei, Henan, and Hunan, only had an incipient market of new energy road trucks; this leaves lots of room to utilize new energy trucks to fulfill freight transportation demand in the future.

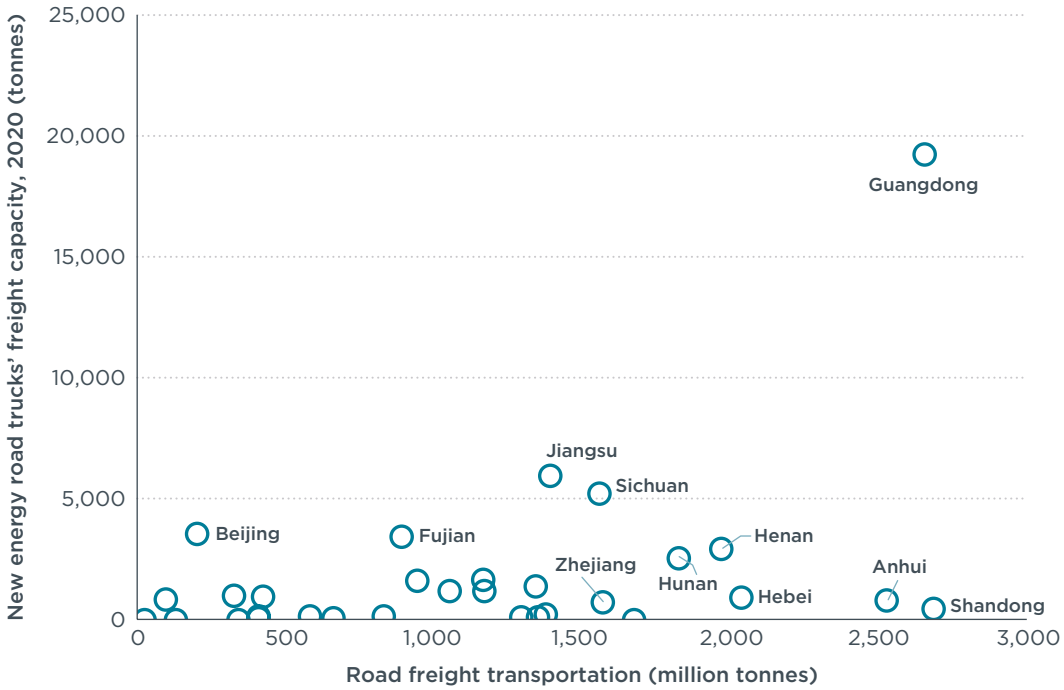


Figure 21. Road freight transported (average of annual tonnes from 2015 to 2020) versus new freight capacity of new energy road trucks in 2020.

Data source: National Bureau of Statistics of China

To conclude this subsection, we summarize our NECV market analysis into the following five features:

- The top 20 city markets in terms of cumulative NECV registrations from 2012 to 2020 were also home to over half of the national NECV market in 2020.
- By 2020, China's NECV market was dominated by heavy commercial vehicles that carry passengers (mostly city buses and coaches) and urban logistics vehicles, which first began to emerge in 2017; heavier trucks did not begin to emerge until 2018.
- In 2020, Tier 1, New Tier 1, and Tier 2 cities deployed nearly 70% of all NECVs nationwide. This was an increase of 7 percentage points compared with 2015.

8 Road trucks here refers to straight trucks, dump trucks, tractor trucks, and urban logistics vehicles.

» The most deployments of NECVs that carry passengers occurred in densely populated areas across China. Urban logistics vehicles were predominantly sold in Guangdong, Sichuan, Jiangsu, and a handful of provinces in Central China. Heavier dump trucks and tractor trucks were mainly used in Northern China and Guangdong.

» Cities and provinces still rely mostly on internal combustion vehicles for freight delivery, and there is immense potential to electrify road freight vehicles.

3.2. ASSESSMENT OF LEADING CITY MARKETS FOR VARIOUS TYPES OF NECVS

This section assesses the leading city markets of five NECV categories: urban logistics vehicles, dump trucks, tractor trucks, city buses, and inter-city passenger vehicles (aka coaches). Figure 22 plots the key market characteristics for the top 10 cities (in terms of new registrations in 2020) for each of the five commercial vehicle categories considered, with the bars (top axis) denoting market size and dots (bottom axis) representing market share in the same categories. Shenzhen realized 100% electrification of its bus fleet in 2017 (Qu & Dai, 2019) and its new registrations of new energy buses in 2020 were too low to enter our top 10 list. The following parts of this section provide analyses of sectoral market characteristics, technical details, and underlying factors driving the NEV success of each set of the leading cities. This analytical structure differs from the NEPC market due to the unique applications of commercial vehicles.

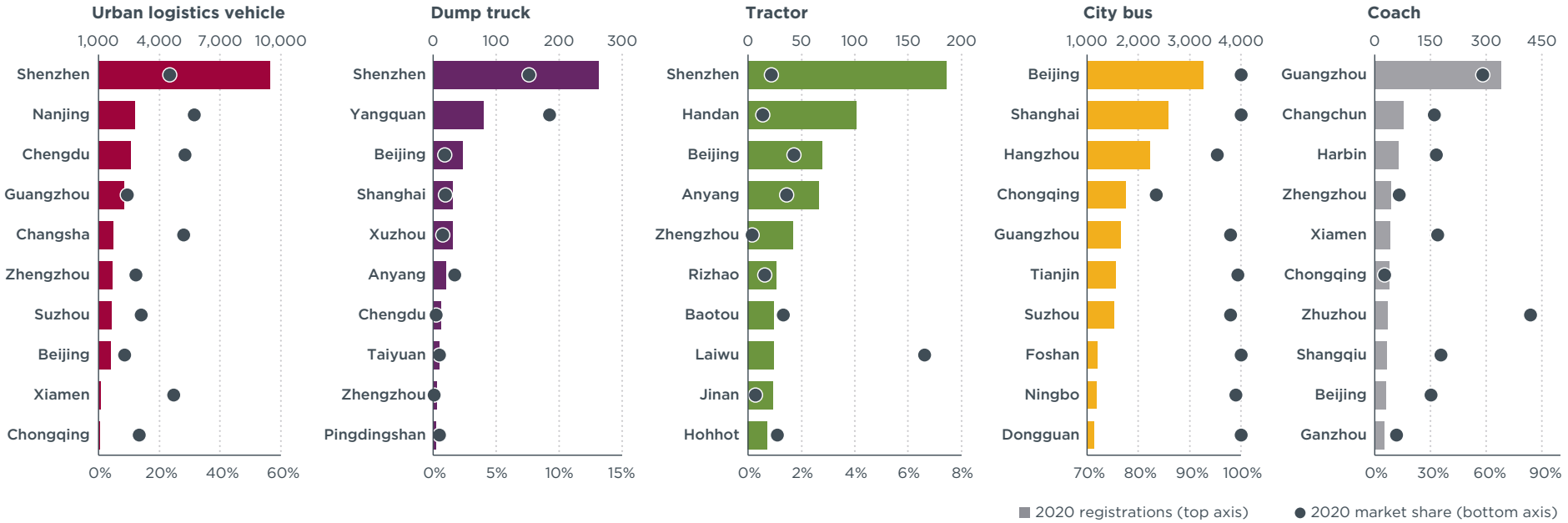


Figure 22. Registrations and market penetration of various types of new energy commercial vehicles in the top 10 cities for each, 2020

3.2.1. Urban logistics vehicles

Registrations of new energy urban logistics vehicles in the year 2020 exceeded 40,000 nationwide. The demand for urban logistics vehicles increased in 2020 mainly because of the surging e-commerce activity associated with COVID-19 lockdowns (Zhu, 2020). The top 10 new energy urban logistics vehicle city markets—Shenzhen, Nanjing, Chengdu, Guangzhou, Changsha, Zhengzhou, Suzhou, Beijing, Xiamen, and Chongqing—comprised more than 60% of the national total, and each exceeded 1,000 sales that year (Figure 22). Half of these cities also surpassed 20% NEV market penetration for the segment.

The pie chart on the left of Figure 23 suggests that the top 10 manufacturers captured nearly three-quarters of the 2020 market for new energy urban logistics vehicles. Each row on the right part of Figure 23 shows the new registrations distribution of 1 manufacturer across the 10 leading cities; the darker the cell, the higher the sales of that manufacturer in that city. It stands out that almost all of the top manufacturers sold most of their vehicles in Shenzhen. Nanjing Golden dragon and Foton were the two exceptions, and they focused primarily on their respective home markets, Nanjing and Beijing.

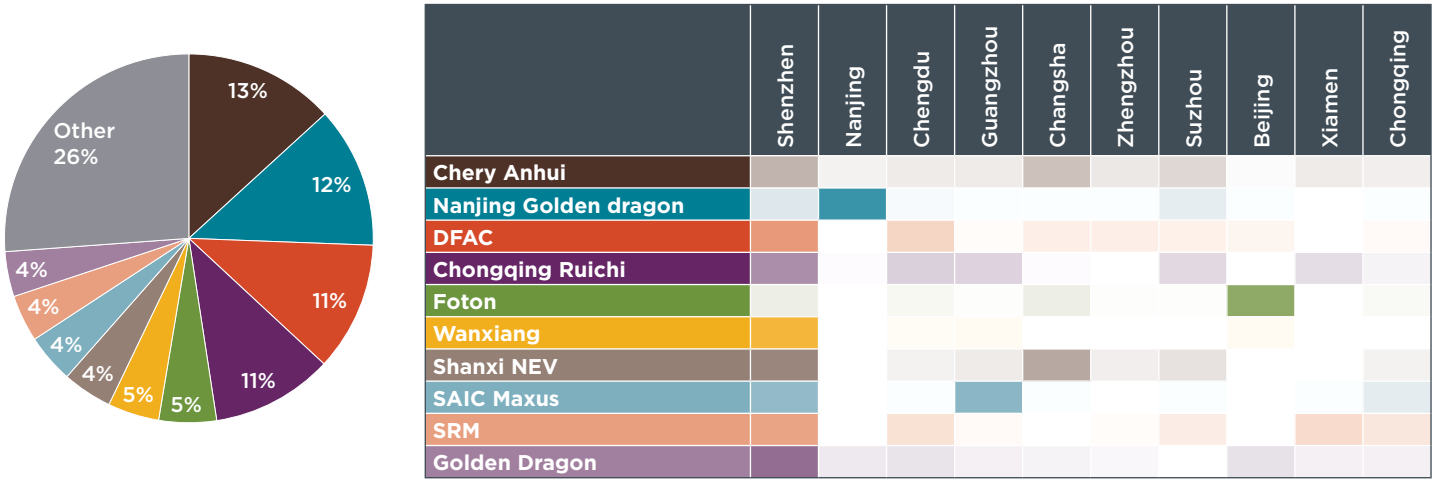


Figure 23. Deployment of new energy urban logistics vehicles in top 10 cities by major OEMs, 2020.

Figure 24 gives technical details in terms of battery technology, gross vehicle weight (GVW), and electric range distributions and the top-selling vehicle models of each of the leading city markets for new energy urban logistics vehicles. Such granular information reflects the kinds of vehicles and technologies that meet the needs of the local delivery industry. BEVs were the predominant NEV type in all these cities. Lithium iron phosphate (LFP) was the most common battery technology in almost all cities, except for Zhengzhou, where ternary lithium battery technology was more prevalent with a share of nearly 60%. The average electric range of new energy urban logistics vehicles in these top cities was 260 km, with minor variation across cities. However, the GVW class ranged from about 2.0 tonnes (Shenzhen, Chengdu, Guangzhou, Xiamen, and Chongqing) to 4.5 tonnes (Chengdu, Suzhou, and Chongqing), implying substantial differences in work duties. Vehicle brands and models in most cities were diversified, but Nanjing and Beijing primarily embraced their locally produced vehicle models.

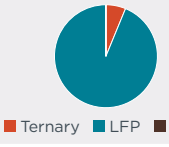
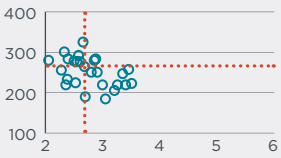
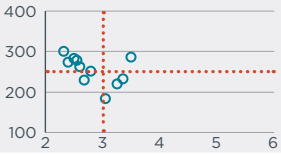
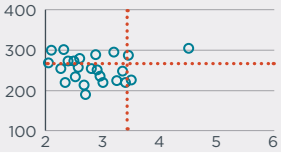
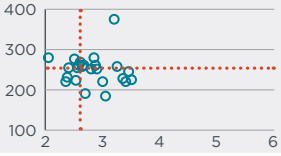
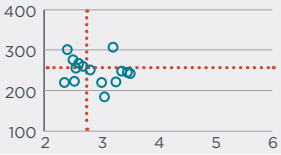
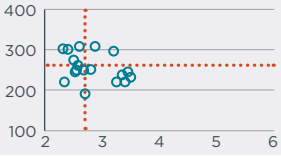
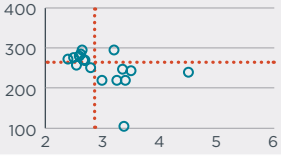
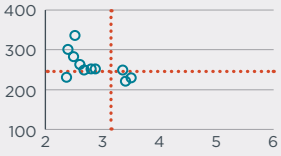
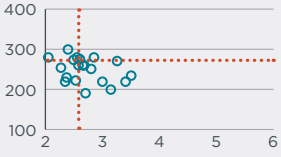
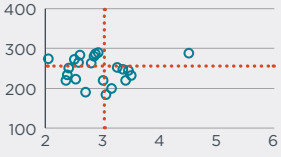
City	Battery technology	E-range (km) distribution by GVW (t)	Top model	Model %	OEM
Shenzhen			Youyou	9%	Chery Anhui
			EV350	8%	DFAC
			Haoyun 1	5%	SRM
			Yuancheng E5L	5%	Shanxi NEV
			EC35	4%	Chongqing Ruichi
Nanjing			Skywell D10	48%	Nanjing Golden Dragon
			Skywell D07	19%	Nanjing Golden Dragon
			Youyou	3%	Chery Anhui
			Skywell E7	2%	Nanjing Golden Dragon
			Skywell K10	2%	Nanjing Golden Dragon
Chengdu			EV350	11%	DFAC
			Youyou	6%	Chery Anhui
			EC35	6%	Chongqing Ruichi
			Haoyun 1	5%	SRM
			J6F	3%	None top OEM
Guangzhou			Youyou	19%	Chery Anhui
			EC35	7%	Chongqing Ruichi
			Changanzhixing 9EV	6%	None top 10 OEM
			Haitun EV	4%	Chery Anhui
			T5	4%	None top 10 OEM
Changsha			Yuancheng E5L	20%	Shanxi NEV
			Haitun EV	17%	Chery Anhui
			EV350	7%	DFAC
			AUMARK Zhilan	5%	Foton
			Youyou	4%	Chery Anhui
Zhengzhou			Zhongdian 360	13%	None top 10 OEM
			EV350	9%	DFAC
			Youyou	9%	Chery Anhui
			Haitun EV	3%	Chery Anhui
			Yuancheng E5L	1%	Shanxi NEV
Suzhou			Haitun EV	13%	Chery Anhui
			EC35	9%	Chongqing Ruichi
			Youyou	9%	Chery Anhui
			Yufeng	7%	DFAC
			Skywell D10	6%	Nanjing Golden Dragon
Beijing			AUMARK Zhilan	23%	Foton
			VIEW Zhilan	6%	Foton
			EV350	5%	DFAC
			T5	1%	None top 10 OEM
			Youyou	1%	Chery Anhui
Xiamen			Haoyun 1	16%	SRM
			Youyou	14%	Chery Anhui
			EC35	8%	Chongqing Ruichi
			Wuling rongguang	2%	None top 10 OEM
			Wuling 50EV	1%	None top 10 OEM
Chongqing			Haoyun 1	11%	SRM
			Ruixing EM80	8%	None top 10 OEM
			Changanzhixing 9EV	7%	None top 10 OEM
			EC35	7%	Chongqing Ruichi
			Haitun EV	6%	Chery Anhui

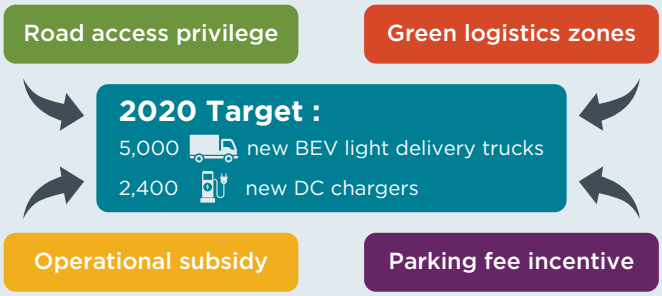
Figure 24. Technical characteristics and top-selling vehicle models of new energy urban logistics vehicles in the top 10 cities for new energy commercial vehicle registrations, 2020.

*Horizontal red line = sales-weighted average electric range in a given city.

**Vertical red line = sales-weighted average gross vehicle weight in a given city.

In 2020, Shenzhen held a wide lead over the other top cities with a new energy urban logistics vehicle market of nearly 10,000 (see Figure 22). This market performance resulted from the city's efforts over consecutive years. Starting in 2018, Shenzhen took "all-inclusive" policy measures to rapidly transition its fleet of urban logistics vehicles to electric. These measures included providing local subsidies for confirmed operation, banning new registrations of conventional fuel logistics vehicles, retiring high-polluting vehicles and replacing them with new energy alternatives, giving road access privileges to electric trucks on otherwise traffic-restricted roads, setting green logistics zones, and requiring the use of only ultra-clean trucks; the city also expanded the buildout of large-scale, centralized charging stations in logistics hubs and commercial areas, and offered parking fee incentives and more.[9] This all helps explain why the city was a favorite market for nearly all major new energy logistics vehicle manufacturers.

BOX 2. COMPREHENSIVE POLICY PACKAGE IN SHENZHEN



AIR-QUALITY-DRIVEN:

NEV deployment was identified as one of the key measures to improve air quality in Shenzhen.

COMPREHENSIVE SET OF TARGETS:

Shenzhen developed a 5-year urban freight distribution development plan focused on promoting new energy delivery trucks (Shenzhen Municipal Transportation Commission, 2017). The 2020 annual target was to promote 5,000 new light battery-electric logistic vehicles and construct 2,400 new fast chargers (Shenzhen Municipal Development and Reform Commission, 2016). In addition, the city's subsequent air-quality-improvement action plan echoed those targets, aiming at a 30% or higher electrification rate in the city's operated light truck fleets (mainly urban logistic vehicles) by the end of 2020 (Shenzhen Municipal Government, 2017).

FOUR MEASURES:

There were many supportive policies in Shenzhen that targeted end-users. Municipal finance subsidized vehicle owners whose BEV logistics vehicles met the minimum operational mileage based on battery capacity, with the highest total subsidy amount of CNY 75,000 per vehicle (Shenzhen Municipal Transportation Bureau, 2020). In addition, NEV owners were incentivized by first-2-hours-free daily street parking and first-2-hours-free daily parking for charging purposes if they parked their vehicles in municipal parks or other non-commercial public parking lots (Shenzhen Municipal Government, 2020; Shenzhen Municipal Development and Reform Commission, 2020). Apart from monetary incentives, road access privileges were also conferred, with light battery electric trucks enjoying the broadest access: permission to drive on almost all roads of the city except for only a couple of streets at specific times (Shenzhen Municipal Public Security Bureau, 2020a). The city also set 10 green zones in which diesel trucks were banned (Shenzhen Municipal Public Security Bureau, 2020b).

Nanjing, Chengdu, and Guangzhou also saw considerable registration of new energy urban logistics vehicles in 2020, all exceeding 2,000 units (see Figure 22), but the key driving forces behind their market performance were slightly different.

Among the cities on the top 10 list, new energy urban logistics vehicles had the highest market share in Nanjing, where one-third of newly registered urban logistics vehicles in 2020 were electric. Unlike Shenzhen, the city did not rely on subsidies to stimulate this market. Note, however, that the city is the home to China's second-largest new energy

9 From internal communication with Shenzhen Municipal Human Settlements and Environment Commission, 2019.

urban logistics vehicle manufacturer in the year 2020, Nanjing Golden Dragon, and the city enjoys the most comprehensive service network from the automaker. Equally important, the city has an inherent advantage in ensuring charging convenience and affordability as Nanjing is the capital city of Jiangsu province, where China's charging service giant StarCharge is located. The company charged about one-fifth of all of China's e-mobility in 2020, and that started with its base province (China Electric Vehicle Charging Infrastructure Promotion Alliance, 2021). Nanjing aimed to install one charger for every two new energy urban logistics trucks by 2021 and offered road access and parking incentives for new energy delivery vehicles (Evpartner, 2020).

Road access policies played a pivotal role in driving Chengdu's new energy urban logistics vehicle market. Chengdu has been under tremendous pressure to improve its local air quality, and thus enacted hard-handed measures in transportation, including restricting the use of certain vehicles in central urban areas on certain days and on severely polluted days; NEVs, including new energy urban logistics vehicles, were exempted from this (Chengdu Municipal Economic and Information Bureau, 2019, Chengdu Municipal Government, 2020).

Guangzhou was the only leading new energy urban logistics vehicle market that did not provide any favorable road access to new energy trucks in 2020, and it did not rely on substantial subsidies, either.[10] The secret ingredient of its early success was the fuel cost savings from frequent use of new energy logistics vehicles. The average daily mileage of an urban freight truck in Guangzhou was about 200 km (Guangzhou Municipal Transportation Bureau, 2020a). The relatively high mileage, combined with convenient and cheap charging, made new energy logistics vehicles an appealing choice for local truck drivers (Evpartner, 2019).

Figure 25 examines the deployment of new energy logistics vehicles relative to the demands of delivery services in cities. We used the number of parcels delivered within cities to estimate the demands of delivery services. Unsurprisingly, the strongest consumer goods markets, including all four Tier 1 cities and several wealthier cities like Hangzhou and Dongguan, were the busiest for the urban logistics industry. Shenzhen was miles ahead of other cities in China in terms of electrifying its urban logistics vehicles (Shenzhen Special Zone Daily, 2021), with over 40,000 units deployed from 2018 to 2020. Beijing and Guangzhou are also catching up, as both cities deployed more than 7,000 new energy urban logistics vehicles during the same time span. However, despite a booming urban logistics industry, Shanghai was behind the other Tier 1 cities in utilizing new energy urban logistics vehicles. Chengdu and Zhengzhou stood out from over a dozen New Tier 1 cities in their success of promoting new energy urban logistics vehicles.

10 Nonetheless, the city does allow electric vehicles to drive on severely polluted days when other motor vehicles are restricted from traveling, and that started in 2021.

Figure 25. Delivered packages versus the number of new energy urban logistics vehicles, 2018 to 2020.

3.2.2. Dump trucks

The market size of new energy dump trucks in 2020 was small compared with other commercial vehicle categories. Only 519 dump trucks were registered nationwide that year, 97% of them in the top 10 cities listed in Figure 22: Shenzhen, Yangquan (Shaanxi province), Beijing, Shanghai, Xuzhou (Jiangsu province), Anyang (Henan province), Chengdu (Sichuan province), Taiyuan (Shanxi province), Zhengzhou (Henan province), and Pingdingshan (Henan province). Because the market share in Shanghai was a little higher than that in Xuzhou, Shanghai took a higher position in our ranking list, even though the two cities had the same number of new energy dump truck registrations in 2020. Only the top five cities reached a threshold of 30 units registered. Shenzhen stood out prominently for its registration volume. Performance in Yangquan was also eye-catching because its market share reached 9.2%, while the top cities' average was only 2.2%.

Figure 26 shows that the top 10 manufacturers were responsible for almost all sales in the 10 leading city markets. Skywell (Shenzhen), Shaanxi Automobile, and SANY were the leaders, with a combined 71% of the market. Notably, almost all the manufacturers in Figure 26 sold their products only to a limited number of city markets. Skywell (Shenzhen) and XCMG sold products only to their home markets, Shenzhen and Xuzhou, respectively. Some manufacturers sold products primarily to nearby cities close to their headquarters. For example, Shaanxi Automobile, whose headquarters is in Xi'an, Shaanxi province, sold 94% of its vehicles to cities in the same province (Yangquan and Anyang). Similar was found for CAMC, FAW, and Beijing Hualin, headquartered in Ma'anshan (Anhui province), Changchun (Jilin province), and Beijing, respectively. On the other hand, SANY, KAMA, Yutong, and BEIBEN TRUCK, whose headquarters are in Changsha (Hunan province), Shouguang (Shandong province), Zhengzhou (Henan province), and Baotou (Inner Mongolia), sold products to cities that were away from their headquarters.

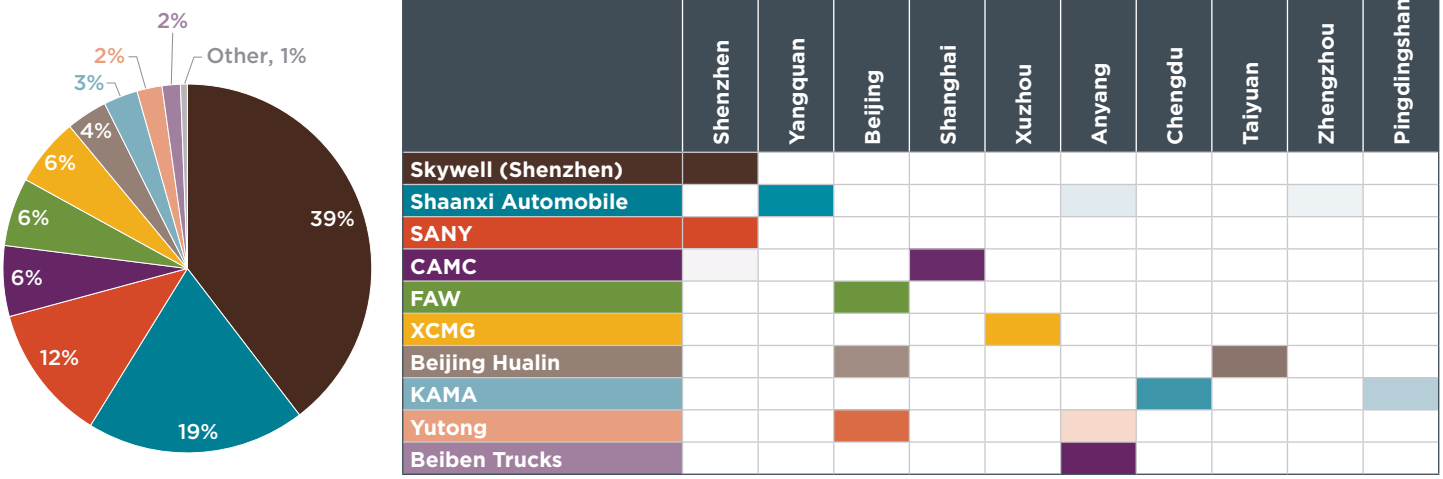
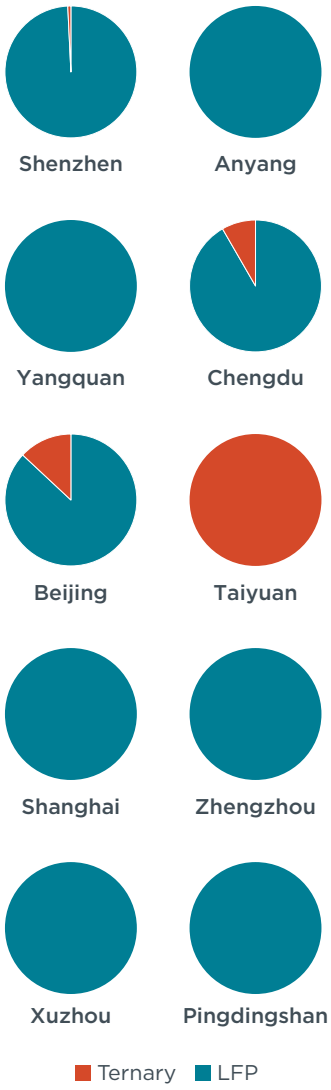
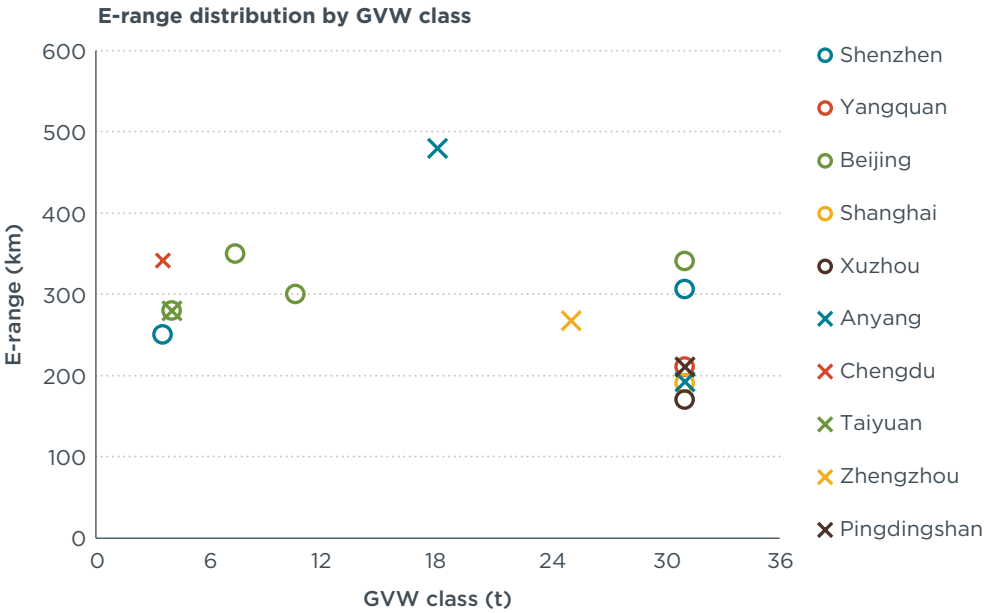


Figure 26. Deployment of new energy dump trucks in top 10 cities by major OEMs, 2020.

Figure 27 provides details of the technical characteristics—battery technology, vehicle weight, and electric range distributions—and top-selling vehicle models of each of the new energy dump truck leading city markets in 2020. New energy dump trucks in those cities were purely BEVs. LFP battery-powered dump trucks were the most popular products in most of the leading cities, with Taiyuan being an exception. The electric range of new energy dump trucks spanned from 170 km to 480 km, with the average being 278 km. Most of these dump trucks fell in the weight class of 31 tonnes, with exceptions in Chengdu and Shenzhen (3.5 tonnes), Taiyuan (4.0 tonnes), Beijing (7.3 and 10.5 tonnes), and Anyang (18 tonnes), and Zhengzhou (25 tonnes). As mentioned above, most of the top 10 manufacturers sold their products to only a few city markets in 2020. Figure 27 has additional model information and shows that most manufacturers sold only one model in cities in which they were leaders.





City	Top model	Model%	OEM
Shenzhen	Unknown model name	75%	Skywell (Shenzhen)
Yangquan	Delongxin M3000	100%	Shananxi Automobile
Beijing	Jiefang J6P	64%	FAW
Shanghai	Hualing	100%	CAMC
Xuzhou	Unknown model name	100%	XCMG
Anyang	Unknown model name	50%	Shananxi Automobile
Chengdu	Ruihang X1	92%	KAMA
Taiyuan	Unknown model name	100%	Beijing Hualin
Zhengzhou	Delongxin M3000	100%	Shananxi Automobile
Pingdingshan	Kaijie HM	100%	KAMA

Figure 27. Technical characteristics and top-selling vehicle models of new energy dump trucks in top 10 cities, 2020.

Improving local air quality was a major motivation for developing the new energy dump truck market in all cities analyzed, and environmental and safety requirements primarily drove Shenzhen's high uptake. Almost all of the new energy dump trucks registered in 2020 in Shenzhen (99%) were in the 31 tonnes weight class (GVW) and these dump trucks are usually used to transport construction materials like dirt, sand aggregates, and gravel. Driven by urban transportation safety concerns and the city's urge to improve local air quality, Shenzhen heavy-duty dump truck replacement project aimed to phase out the use of conventional-fuel trucks by mid-2019 (Housing and Construction Bureau of Shenzhen Municipality, 2018; Transportation Commission of Shenzhen Municipality, 2018). Fleet owners could receive subsidies as high as CNY 230,000 (in 2019) or CNY 66,500 (in 2020) by scraping their conventional-fuel trucks. Shenzhen also adopted a 5-year program in 2018 that offered additional grants for operating new energy heavy-duty dump trucks: a per-truck incentive of up to CNY 800,000 allocated in consecutive years if specific technical and annual mileage requirements are met (Development and Reform Commission of Shenzhen Municipality, 2018). Lastly, Shenzhen also used pilot projects to forge and enhance its industrial leadership in new energy trucks. These pilot projects involved sales from both Shenzhen's local OEM, Skywell and a top-notch nonlocal OEM, SANY (Shenzhen Municipal Bureau of Industry and Information Technology, 2019).

The 80 dump trucks registered in Yangquan in 2020 were part of a public-private partnership to address air pollution caused mainly by activities associated with its coal industry. The city was enlisted as a key pollution-control region (China National Environmental Monitoring Center, 2021; Yangquan Municipal Government, 2020) and one key measure was to replace the dirty diesel trucks deployed by the coal mining industry with clean and new energy alternatives (Yangquan Municipal Government, 2020). The city facilitated several pilot projects, and a procurement contract was granted to Yangmei Group for 80 heavy-duty electric trucks (Nie, Zhang, & Meng, 2020).

In 2020, the Beijing municipal government procured 47 new energy dump trucks to help tackle local air pollution; 17 of them were garbage trucks, and the other 30 joined the city's construction fleet (Yu & Dong, 2020). This was guided by *Beijing's local Three-Year Plan to Win the Battle Against Air Pollution*.

Shanghai set a goal of deploying 5,000 new energy trucks from 2018 to 2020 in multiple environmental and transportation action plans (Shanghai Municipal Government, 2018a; Shanghai Municipal Government, 2019). Shanghai's key measures included providing incentives to replace diesel dump trucks with NEVs and allowing new energy trucks to drive in central urban areas (Shanghai Municipal Transportation Commission, 2016).

With an ambition to forge a world-class production base, Xuzhou focused on developing its local new energy industry, including manufacturing NEVs and their components (Fan, 2020). In 2020, the city launched a pilot battery-swapping project for dump trucks, with 30 new energy dump trucks meant to ship construction dirt developed jointly by State Grid and Xuhou's local heavy machine manufacturer Xuzhou Construction Machinery Group (XCMG; Gu, 2020). Because of the overall success of XCMG and the large amount of attention the local government paid to the new energy vehicle industry, Xuzhou attracted many NEV enterprises that built production bases there, including Chery Commercial Vehicles, and this has become a vital economic pillar of the city (Sohu News, 2017b; Xuzhou Daily, 2019; Wireless Xuzhou, 2021).

3.2.3. Tractor trucks

The new energy tractor truck market is still nascent. A total of 686 new energy tractor trucks were registered in all of China in 2020. Over 80% of these were in the top 10 cities listed in Figure 22: Shenzhen, Handan (Hebei province), Beijing, Anyang (Henan province), Zhengzhou (Henan province), Rizhao (Shandong province), Baotou (Inner Mongolia), Laiwu (Shandong province), Jinan (Shandong province), and Hohhot (Inner Mongolia). But only in the first four cities did the registration of new energy tractor trucks exceeded 50 units that year, and Shenzhen was the leader by deploying 190 of the vehicles in 2020. The average market share of new energy tractor trucks in these top cities was only 0.6%, but Beijing and Anyang had greater market shares of 1.7% and 1.4%, respectively. Although Laiwu had the highest percentage of new energy tractor trucks at 6.6%, its overall tractor truck market was quite small—less than 400—and thus it is not considered a good exemplar.

Figure 28 shows there were only eight vehicle manufacturers in the top 10 new energy tractor truck city markets and two of the manufacturers, CAMC and Beiben Heavy Trucks, were the clear leaders. These two represented over 80% of the top 10 cities' combined market and sold their vehicles in multiple cities. The other companies sold their vehicles to only a couple of cities and Foton primarily focused on its home market of Beijing.

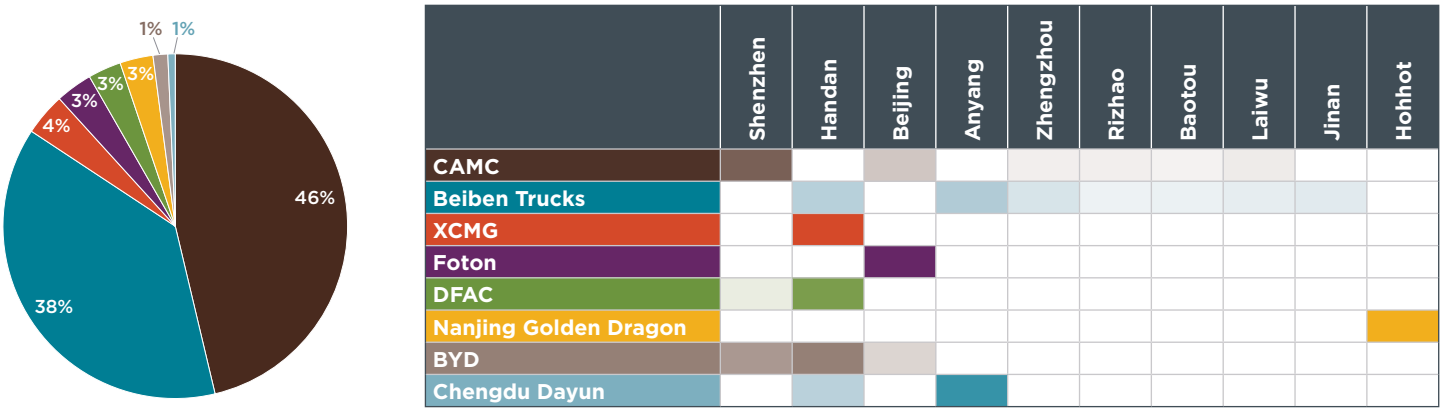


Figure 28. Deployment of new energy tractor trucks in the top 10 cities by major OEMs, 2020.

Figure 29 provides the detailed technical characteristics—gross combined vehicle weight (GCVW) and electric range—and top-selling vehicle models of each leading new energy tractor truck city market. Note that almost all of the new energy tractor trucks in these city markets were BEVs powered by LFP batteries, and thus that information is not displayed in the figure. The electric range of each weight class ranged from 170 km to 255 km, with an average of 203 km. Most of these trucks fell in the weight class of 49 tonnes. Beiben V3, from Beiben Trucks, and Hanma H7, from Valin Xingma, were the most popular new energy tractor truck products.

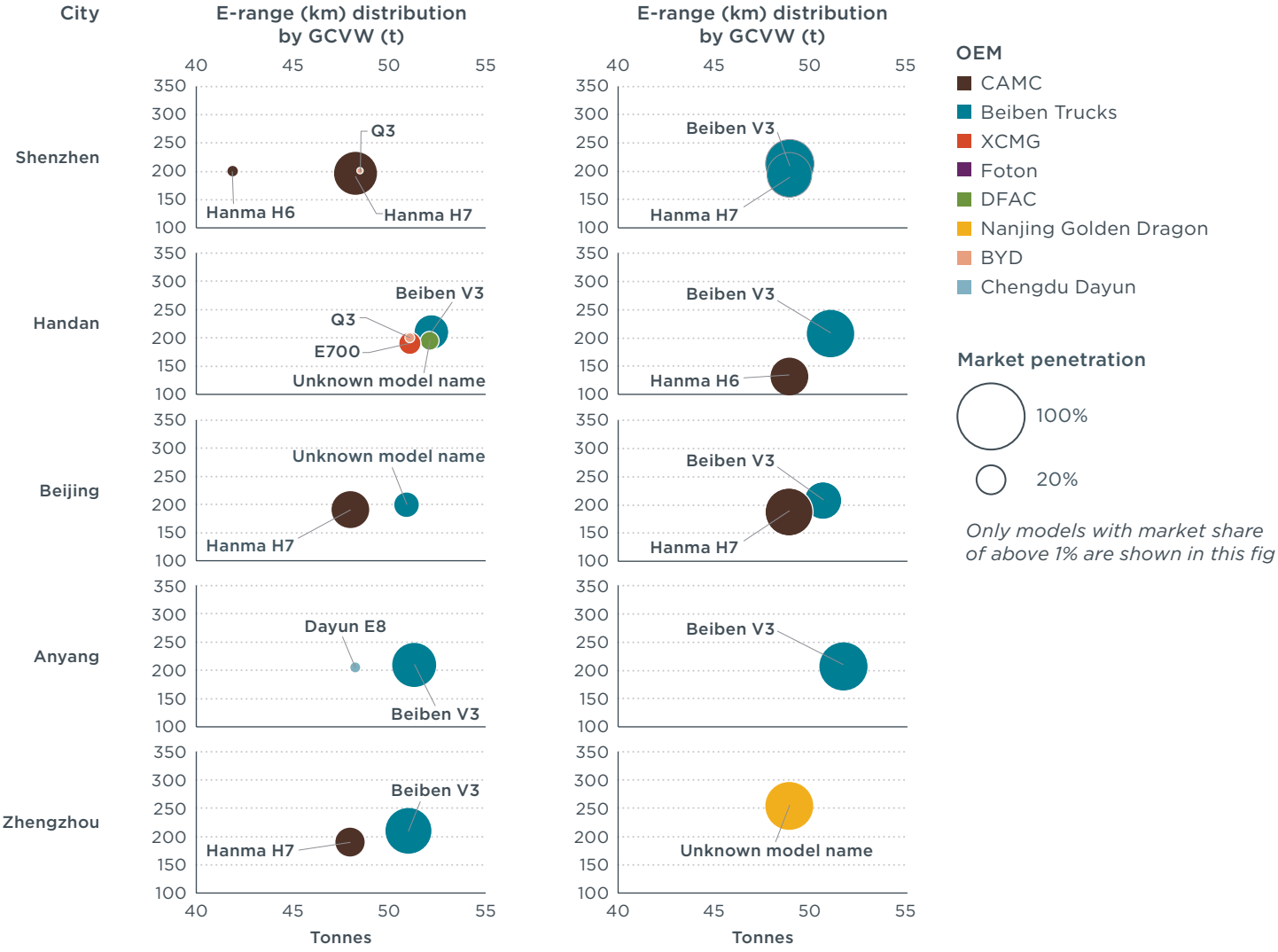


Figure 29. Technical characteristics and top-selling vehicle models of new energy tractor truck in the top 10 cities, 2020.

BOX 3. CLEAN TRANSPORTATION REQUIREMENT FOR THE STEEL INDUSTRY

The steel industry is China's second-largest source of air pollution, only behind the power sector, and nearly 30% of its emissions were associated with the transportation of raw materials (e.g., iron ores, limestone), energy (coal and coke), finished steel products, and wastes. To address this, China's three-year *National Plan of Blue-Sky Defense* and a series of detailed government guidelines since 2018, including the *Implementation Guidelines on Promoting an Ultra-low Emission Steel Industry* by the Ministry of Ecology and Environment, targeted clean transportation as a key measure for cleaning up the steel industry. The Guidelines required steel companies to use railway, waterway, belt, or pipeline for at least 80% of feedstock transportation. For companies unable to attain this ratio, the only alternative was to use zero-emission or China VI-compliant trucks.

Environmental policies were a key driver behind the sales of new energy tractor trucks in all top city markets in 2020. In its 2017–2020 Air Quality Improvement Plan, the city pledged to achieve world-class healthy air quality for its residents by 2020 (Shenzhen Municipal Government, 2017). To fulfill the promise, the city developed annual "Shenzhen Blue" action plans, in which electrifying trucks in the urban construction and urban delivery industries, and at airports, has been a pivotal element (Shenzhen Municipal Bureau of Ecology and Environment, 2018). In putting those plans into action, the city joined with CAMC to replace old and high-polluting tractor trucks at port terminals with zero-emission alternatives (Sohu News, 2018). In 2020, the city purchased 181 new energy tractor trucks from CAMC, and that was more than 90% of the city's new energy tractor truck deployment that year.

Handan deployed over 100 new energy tractor trucks in 2020, and this was driven by environmental requirements for the steel industry. Handan is one of China's heavy industry centers and a major producer of coal and steel (Sohu News, 2019a). While there was a lot of GRP associated with the steel industry, this came with pollution and the city was repeatedly listed among the cities in China with the most polluted air (Gao, 2018). In addition, to fulfill the ultra-clean truck utilization requirement from the central guidance, Handan city created low-emission zones for freight trucks that banned the use of high-emitting (certified to the China IV emission standard or below) trucks in central urban areas (Hou, 2020). Because the model options of China VI emission standard truck models were sparse before 2021,[11] the environmental policies triggered a round of zero-emission truck procurement contracts from steel companies in Handan. The five largest steel companies—Hesteel, Hansteel, Yuhua, Xinjin, and Puyang—signed contracts to buy or lease more than 500 new energy tractor trucks and these were to be put into operation starting in 2020 (Hou, 2020). The typical new energy tractor truck model deployed by Handan's steel producers was the Beiben V3 from Beiben Trucks. The truck features a 280 kWh LFP battery, 210 km electric range, and a 50-tonne maximum gross combined weight; in combination, this provides sufficient capacity to transport raw materials between the companies' various production sites.

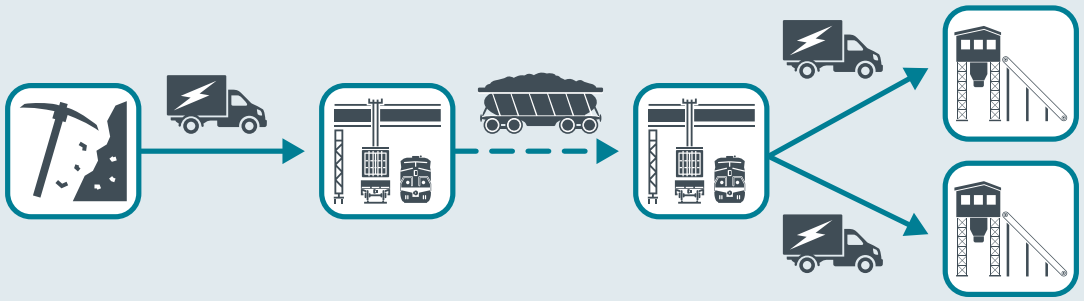
In 2020, Beijing deployed 69 new energy tractor trucks, primarily Valin's battery-swappable model, which uses a 282 kWh LFP battery, has a 200 km electric range, and has up to 48-tonne gross combined vehicle weight. The trucks were mostly sold to Road-Rail Green Intermodal Transportation. They were used to serve the short-distance transportation of construction materials under a pilot initiative *Green Construction Supply Chain Alliance* (Hai, 2020). The initiative was a collaboration among freight

11 While the China Stage VI emission standard for heavy-duty vehicles came into full effect in July 2021, the certification of new models could be done as early as 2019.

logistics companies, mining and construction industry partners, NEV manufacturers, and power companies, with clear goals to reduce emissions associated with road-based transportation and build an ultralow-emission supply chain of construction materials.

The initiative was born out of Beijing's *Three-Year Plan to Win the Battle Against Air Pollution* (a provincial version of China's three-year *National Plan of Blue-Sky Defense*), which required substantial modal shift of bulk products shipment from road to rail and heavy promotion of NEVs (Beijing Municipal Ecology and Environment Bureau, 2018). The construction and mining industry turned out to be a perfect application case in Beijing to combine mode shift and electric vehicles. Thanks to its rapid urbanization and surging demand for construction materials, the city is a major consumer of sand gravel aggregates, and around 30% of its truck-based freight transportation was related to the construction industry (Li, 2021). Hence, the city issued a more specific *Guidance of Green Supply Chain for the Construction Gravel Industry* following the three-year plan. Moreover, the spatial distribution of the gravel mines and cement plants supplying the Beijing area were perfect for piloting the use of heavy new energy trucks for "last-mile" shipping of raw gravel from the mining sites located in the outskirts of Beijing to an intermodal rail station, and then from the destination rail station to cement plants in the city (China Aggregates Association, 2020).

BOX 4. NEW ENERGY TRACTOR TRUCKS FOR BEIJING'S GREEN CONSTRUCTION SUPPLY CHAIN PILOT



APPLICATION CASE

The new energy tractor trucks are used for the "last-mile" shipping of raw gravel from mining sites located in the outskirts of Beijing to intermodal rail stations, and then from the destination rail stations to cement plants in the city. The entire route is typically less than 150 km, with about 100 km of that railway transportation (Hong, 2020).

Key technologies (Hong, 2020)

- Heavy-duty electric trucks
- 5-minute battery swapping on-site at gravel mines
- Standardized, specially designed containers to enable seamless connection between rail and road shipping of gravel

COSTS AND BENEFITS

According to Road-Rail Green Intermodal Transportation, the average daily mileage of its new energy tractor trucks was between 650 km and 800 km. From the inception of the initiative in late 2019 to mid-2021, the entire truck fleet of 111 electric trucks shipped gravel over 5 million km. Assuming a typical heavy-duty diesel truck did the same job and considering an average 50 L/100km fuel consumption rate in real-world driving conditions, we see that using electric trucks reduced more than 2.3 million liters of diesel fuel use and avoided roughly 6,200 tonnes of CO_2 emissions. It is also estimated the energy/fuel cost saving of using the electric trucks has amounted to CNY 9.8 million so far for the entire fleet.

3.2.4. City Buses

In 2020, over 83%, or about 60,000 of the new city buses registered in China were new energy. Ninety percent of Chinese cities exceeded a 90% new energy share in their new city bus fleets, and many had already realized 100% new energy fleets (see Figure 22).

Figure 30 indicates that in 2020, the top 10 manufacturers captured more than three-quarters of the combined market of the 10 leading cities we identified. Foton, SUNWIN, CRRC TIMES, HIGER, BYD, and Yutong almost evenly shared a combined 56% of these markets. Many automakers sold mainly to their home markets. Because city bus fleets are usually owned and operated by local public transportation companies that are subsidized by the local fiscal budget, they tended to deploy bus products that were locally produced.

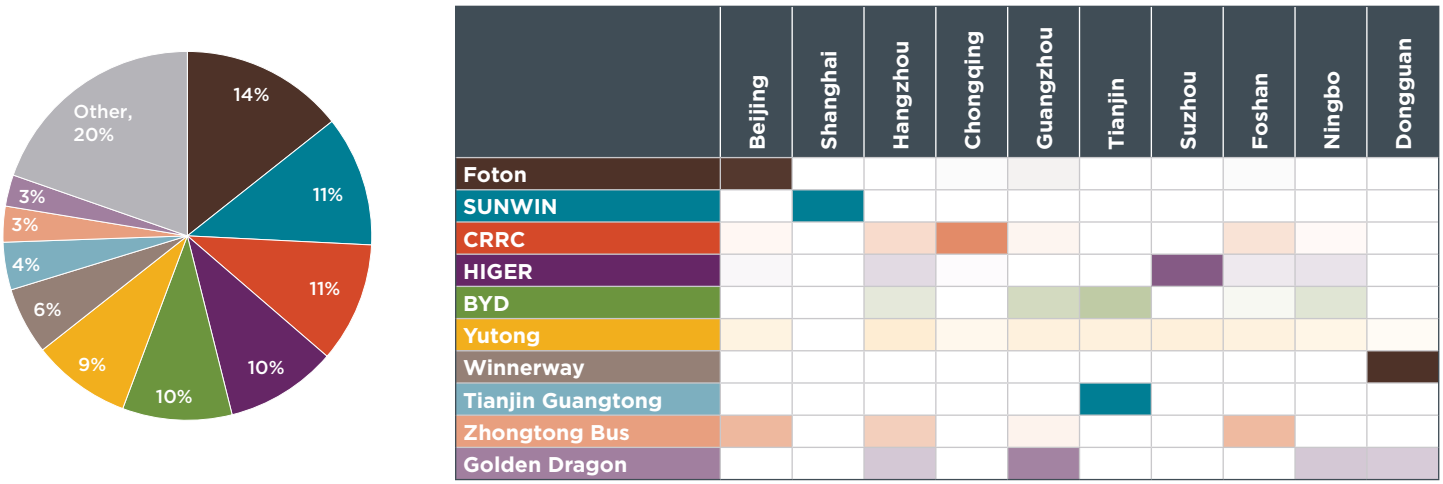


Figure 30. Deployment of new energy city buses in the top 10 cities by major OEMs, 2020.

Figure 31 shows the technical features—vehicle technology, battery technology, gross vehicle weight, and rated power distributions—and top-selling vehicle brands of each of the 10 leading city markets for new energy city buses. The prevailing new energy technology in city bus fleets varied: plug-in hybrid buses dominated over 60% of the market in Chongqing and Beijing, but battery-electric buses prevailed in the rest of the leading cities, particularly Shanghai and Dongguan, which deployed only battery-electric buses in 2020. Noticeably, Guangzhou and Foshan were two forerunners in deploying fuel cell electric buses, and that was influenced by their hydrogen industrial development (Guangzhou Municipal Development and Reform Commission, 2020; Liang, 2021; QN. BJX News, 2021). LFP was the most popular new energy bus battery technology, with Tianjin being an exception. Lithium manganese oxide (LMO) was the second most popular new energy city bus battery technology, as nine out of the 10 leading markets embraced the technology to some extent. The average rated power of city buses in the leading cities was 179 kW, with slight variation across cities. However, gross vehicle weight varied greatly across and within cities. For instance, it went from 7.5 tons to 28 tonnes in Guangzhou and 5.5 tonnes to 25 tons in Hangzhou. Due to data availability, we showcase the besting-selling new energy city bus brands instead of the top five models, as in the previous section. As shown, most of those leading cities favored local new energy bus brands, which echoes our previous analysis for Figure 30.

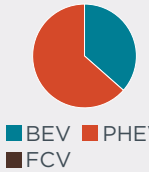
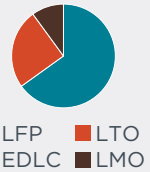
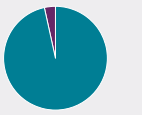
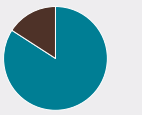
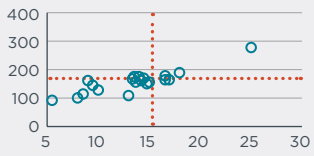
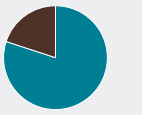
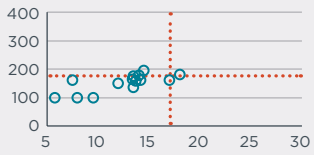
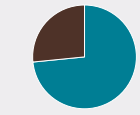
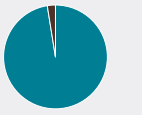
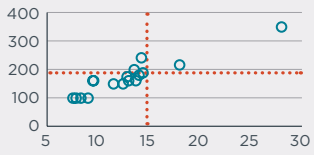
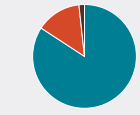
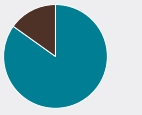
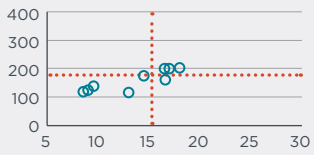
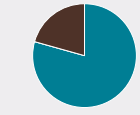
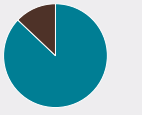
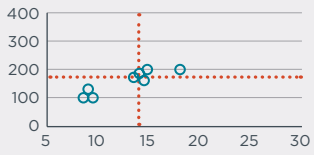
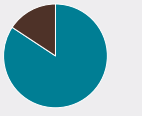
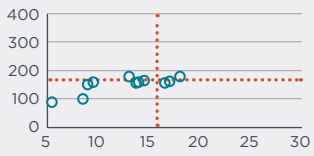
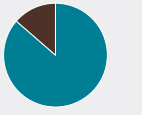
City	Vehicle technology	Battery technology	Rated power (kW) distribution by GVW (t)	Top brand	Market %	OEM
Beijing				Foton	73%	Foton
				Guangtong	9%	None top 10 OEM
				Zhongtong	6%	Zhongtong Bus
				Yutong	5%	Yutong
				Golden Dragon	4%	Golden Dragon
Shanghai				SUNWIN	77%	SUNWIN
				Xiang	18%	None top 10 OEM
				Shenlong	4%	None top 10 OEM
Hangzhou				BYD	20%	BYD
				Yutong	14%	Yutong
				China Zhongche	14%	CRRC
				Yuancheng	11%	CRRC
				HIGER	11%	HIGER
Chongqing				China Zhongche	68%	CRRC
				Yaxing	13%	None top 10 OEM
				Yutong	8%	Yutong
				Golden Dragon	4%	Golden Dragon
				Foton	2%	Foton
Guangzhou				GAC	26%	None top 10 OEM
				Skywell	16%	None top 10 OEM
				Weichiteng	15%	None top 10 OEM
				Jinlv	14%	Golden Dragon
				Yutong	12%	Yutong
Tianjin				Guangtong	46%	SUNWIN
				Jinma	41%	BYD
				Yutong	13%	Yutong
Suzhou				HIGER	81%	HIGER
				Yutong	14%	Yutong
				Kinglong	4%	None top 10 OEM
				Ankai	1%	None top 10 OEM
Foshan				Feichi	26%	None top 10 OEM
				China Zhongche	19%	CRRC
				Zhongtong	16%	Zhongtong Bus
				Yutong	15%	Yutong
				HIGER	9%	HIGER
Ningbo				China Zhongche	29%	CRRC
				BYD	26%	BYD
				Yuancheng	13%	None top 10 OEM
				Yutong	12%	Yutong
				HIGER	12%	HIGER
Dongguan				Winnerway	89%	Winnerway
				Jinlv	7%	Golden Dragon
				Yutong	4%	Yutong

Figure 31. Technical characteristics and top-selling vehicle brands of new energy city buses in top 10 cities, 2020.

*Horizontal red line: sales-weighted average rated power in a given city.

**Vertical red line: sales-weighted average gross vehicle mass in a given city.

The triumph of China's new energy city bus sector can be explained mainly by policies. City buses were prioritized in China's early NEV strategies and in the Ten Cities, Thousand Vehicles pilot program. In 2015, China set a goal of deploying 200,000 new energy buses by 2020 (MOF, 2015). In 2018, China's three-year *National Plan of Blue-Sky Defense* required certain key cities (most of these are municipalities and provincial capitals) to replace all of their buses operated in urban built-up areas with new energy vehicles by 2020 (China State Council, 2018). These policies, combined with massive financial subsidies from the central government and local governments, helped expedite the transition. After 2019, even as the central purchase subsidy phased down, local governments can still provide both purchase and operation subsidies for new energy buses (MOF, 2019a, 2019b).

Leading city markets like Beijing and Shanghai allocated funds for promoting new energy buses. One of the major expenditures of Beijing's CNY 14 billion dedicated energy-saving and environmental protection funds in 2020 was in support of the operation of new energy buses (Beijing Municipal Finance Bureau, 2021). Shanghai aimed at replacing 2,500 buses with new energy ones in 2020 as a last push to fully electrify its city bus fleet (Shanghai Municipal Development and Reform Commission, 2020; Shanghai Municipal Government, 2018b). The primary portion of the city's CNY 781 million extra cost of municipal finance in 2020 was used for new energy bus purchase (Shanghai Municipal Transportation Commission, 2021).

Hangzhou, Chongqing, and Guangzhou continued to provide city-level purchase subsidies for new energy city buses in 2020; these were portions of the size of the central subsidy, 50% in Hangzhou and Guangzhou, and 20% in Chongqing (Hangzhou Municipal Finance Bureau, 2019; Guangzhou Municipal Transportation Bureau, 2020b; Chongqing Municipal Finance Bureau, 2020). Guangzhou provided up to CNY 590,000 CNY per vehicle as an operational award for BEV buses after 8 years in operation, with proof of 30,000 kilometers of mileage per year for each of the 8 years (Guangzhou Municipal Transportation Bureau, 2020c). In addition, Hangzhou and Chongqing subsidized the construction of charging infrastructure for buses: Hangzhou paid for 30% of the total construction investment, and Chongqing offered a CNY 400 per-kW subsidy, with an additional CNY 0.3 per-kWh charging subsidy for buses.

3.2.5. Coaches

In 2020, 1,471 new energy coaches were registered in China, nearly 50% of them concentrated in the top 10 leading cities, which were Guangzhou, Changchun (Jilin province), Harbin (Heilongjiang), Zhengzhou (Henan), Xiamen (Fujian), Chongqing, Zhuzhou (Hunan), Shangqiu (Henan), Beijing, Ganzhou (Jiangxi). Guangzhou stood out with over 300 new energy coach registrations, while the rest of the leading cities deployed under 100 units. Seven out of the 10 leading cities achieved at least 20% market penetration; the highest rate was in Zhuzhou, at 83%.

Even though more than 10 vehicle brands supplied the leading cities, Yuztong dominated the market with nearly 500 vehicles sold, 66% of the market; CRRC followed with 10% of the market and then King Long was third with an 8% share (Figure 32). Yutong's products penetrated almost all of the leading local markets, except for Beijing and Zhuzhou. Foton and CRRC sold mainly in their manufacturing base cities of Beijing and Zhuzhou, respectively.

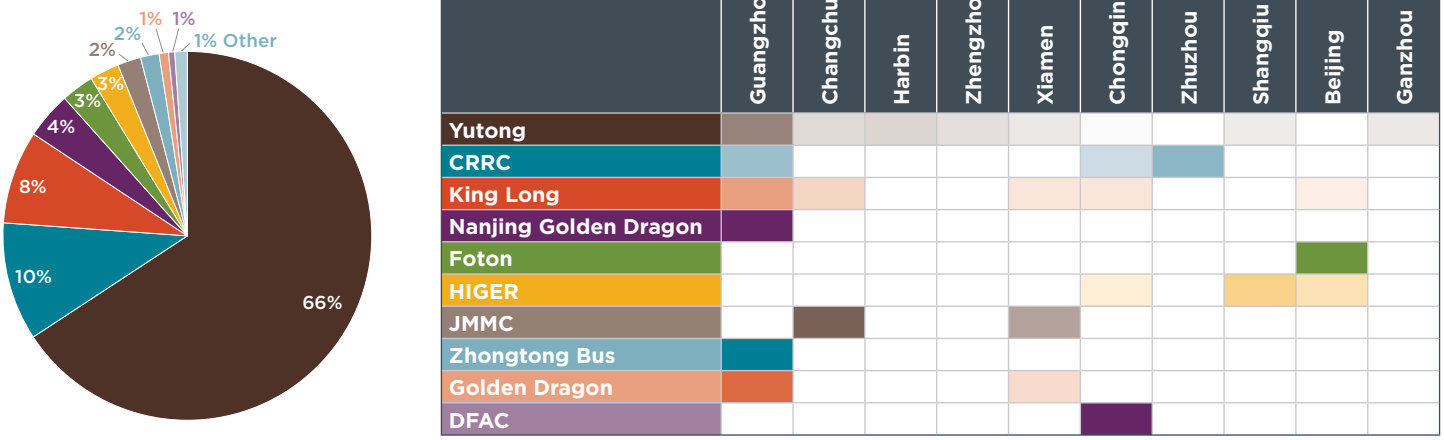


Figure 32. Deployment of new energy coaches in top 10 cities by major brands, 2020.

Figure 33 provides the details of technical characteristics in terms of vehicle weight and battery capacity distributions and of the top-selling vehicle brands of each leading market for coaches. All the cities used battery-electric coaches with LFP batteries. The average battery capacity of coaches was 51 kWh, but variation across cities went from 7 kWh (Zhuzhou) to 293 kWh (Chongqing). Generally, the gross vehicle weight of coaches in those leading cities ranged from 2.4 tonnes to 18 tonnes across cities with variances within cities. Due to data availability, we only display the top-selling new energy coach brands and found cities embraced a limited number of brands. Yutong was the best-selling brand among eight of the 10 leading cities. Notably, this brand was the only new energy coach supplier of Harbin, Zhengzhou, and Ganzhou.

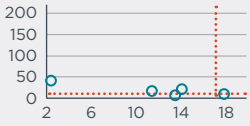
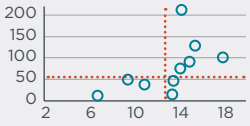
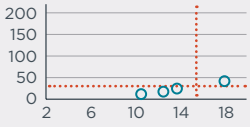
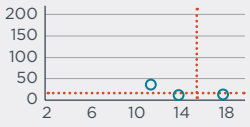
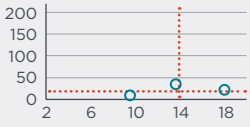
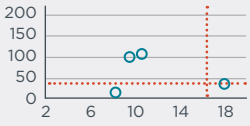
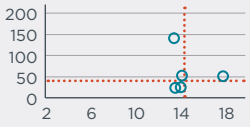
City	Battery capacity (kWh) distribution by GVW (t)	Top brand	Brand %	City	Battery capacity (kWh) distribution by GVW (t)	Top brand	Brand %
Guangzhou		Yutong	68%	Chongqing		Yutong	25%
		Sky well	9%			CRRC	24%
		King Long	9%			Golden Dragon	15%
		CRRC	8%			King Long	12%
		Zhongtong	4%			DFAC	7%
Changchun		Yutong	72%	Zhuzhou		CRRC	100%
		Golden Dragon	15%				
		Jingma	13%				
Harbin		Yutong	100%	Shangqiu		Yutong	70%
						Higer	30%
Zhengzhou		Yutong	100%	Beijing		Foton	68%
						Higer	19%
						King Long	13%
Xiamen		Yutong	69%	Ganzhou		Yutong	100%
		King Long	17%				
		Jingma	12%				
		Golden Dragon	2%				

Figure 33. Technical characteristics and top-selling vehicle brands of new energy coaches in the top 10 cities, 2020.

Guangzhou's strong push to electrify its coach fleets succeeded in getting all major companies to sell in its market. Guangzhou is the capital city of Guangdong province. Located right in the center of the province, it serves as a regional passenger transportation hub connecting cities within and outside the province, and therefore has a large market for coaches. As part of the efforts to implement the city's NEV deployment plan, Guangzhou required new energy coaches in its governmental procurement plans and bids (Guangzhou Municipal Government, 2017). In August 2020, the Municipal Transportation Bureau of Guangzhou released a tender of 700 new energy intercounty coaches (Guangzhou Municipal Transportation Bureau, 2020d). The city also provided a local purchase subsidy for new energy buses at half the national subsidy and an operational subsidy of up to CNY 590,000 per vehicle; the subsidy limit and requirements were the same as for city buses, as detailed in the previous section (Guangzhou Municipal Transportation Bureau, 2020b).

In 2020, Changchun deployed 76 new energy coaches, about one-third of its new coach fleet that year. Changchun's success was mainly due to its intercity coach industry's effort in upgrading its business and services. In recent years, the industry lost a substantial fraction of its market to high-speed rail and ride-hailing. To combat this challenge, local coach companies launched a major reform to revitalize the business, including increasing the frequency of departure and the number of stops along the route, and using NEVs because of the better user experience that comes from the modern design, quietness, and zero tailpipe emissions (Sohu News, 2021b; Sohu News, 2019b). Also, NEV purchase subsidies were still in place at the time (25% the size of central governmental subsidy) and using new energy coaches allows companies to save sizable amounts on fuel costs. Zero-emission coach fleets have now become an important part of Changchun's intercity mobility solution.

4. DRIVING FACTORS OF THE NEV DEVELOPMENT IN CHINESE CITIES

Having shown how NEV development in Chinese cities corresponds with socio-economic development, industry composition, development strategies, and policies, this section examines these factors in detail and attempts to generalize their impact. Charging infrastructure also plays a crucial role in NEV promotion, but lack of data prevents analysis of this at the city level. In this section, we analyze the passenger car and commercial vehicle markets separately, where appropriate.

4.1. ECONOMIC FACTORS

NEV market shares tend to be higher in wealthier cities and regions. This is intuitive, because today's NEVs still cost more upfront than their ICE counterparts. Earlier in China's NEV development, large government subsidies might have eliminated that difference in upfront cost, but in recent years the subsidies have been dramatically reduced and NEVs became less affordable upfront, especially for private consumers. There are also secondary factors, such as better charging networks in economically advanced regions.

Figure 34 shows a strong, positive correlation between the average per capita disposable income and private NEPC penetration in Chinese provinces in 2020.[12] Hainan and Guangxi were the outliers, as both had lower per capita income (approximately one-third of that in Tier 1 cities) but high shares of NEPCs. Their markets are great examples of how local policies and local industrial development strategies strongly impact market development, as discussed in detail earlier.

For commercial vehicles we focused on the truck market and switched the analytical economic factor from disposable income to GRP, because most new energy trucks are not purchased by individuals. However, no clear correlation between GDP and new energy truck market penetration was observed (Figure 35). The new energy truck market was mainly influenced by policies, which will be discussed in the next subsection.

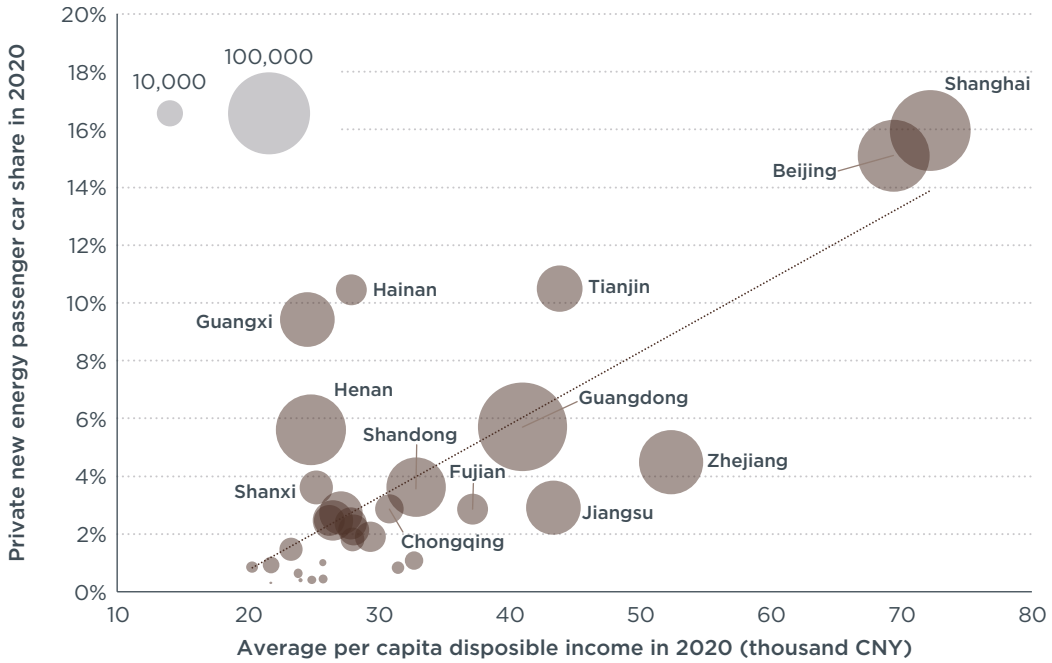


Figure 34. Correlation between private new energy passenger car market share and average per capita disposable income in Chinese provinces, 2020.

*Bubble size denotes private new energy passenger car registrations in given markets

12 To capture broader cities differences and more general trends, we zoomed out our analytical lens from leading cities to each province in mainland China.

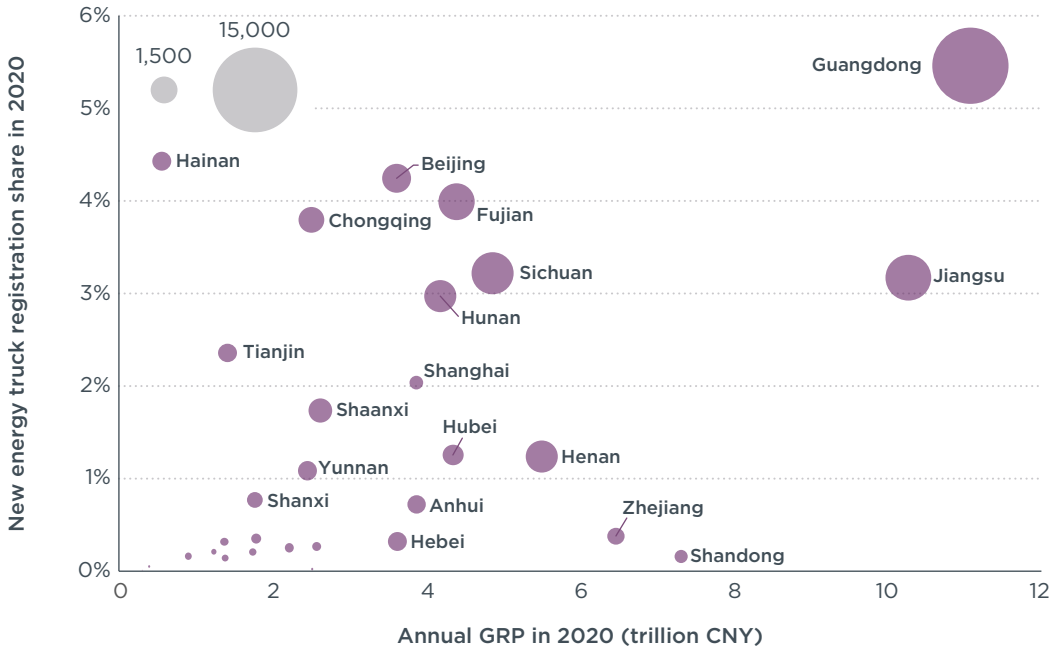


Figure 35. Correlation between new energy trucks' market share and GRP of Chinese provinces, 2020.

*Bubble size denotes new energy truck registration in given markets.

4.2. INDUSTRIAL DEVELOPMENT FACTORS

Local industrial development strategies and policies also had a clear impact, and Figure 36 shows that cities with a more complete NEV industrial supply chain and greater agglomeration levels tended to have higher NEPC market penetration. The average NEPC market share of cities with both strong NEV OEMs and battery producers was 11% in 2020, two percentage points higher than cities with only NEV manufacturers, and four points higher than those with only battery manufacturers.

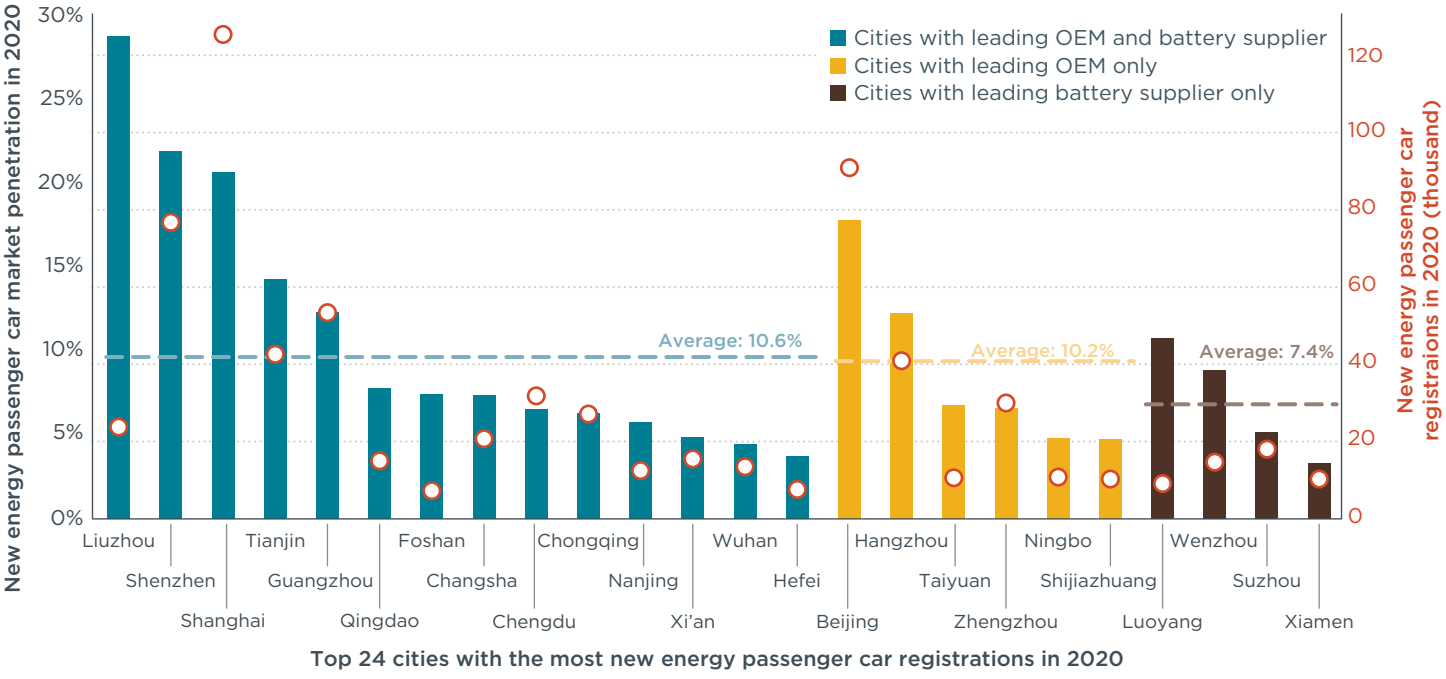


Figure 36. New energy passenger car market share (bars and left y-axis), registration volume (dots and right y-axis), and NEV industrial competitiveness of 24 leading cities, 2020.

*Cities are categorized into three groups by industry strategy and ordered by their new energy passenger car penetration in each group.

Figure 37 shows private NEPC registrations were strongly positively correlated with the number of models registered in 2020, but a similar correlation was not seen in the NECV market in Figure 38.

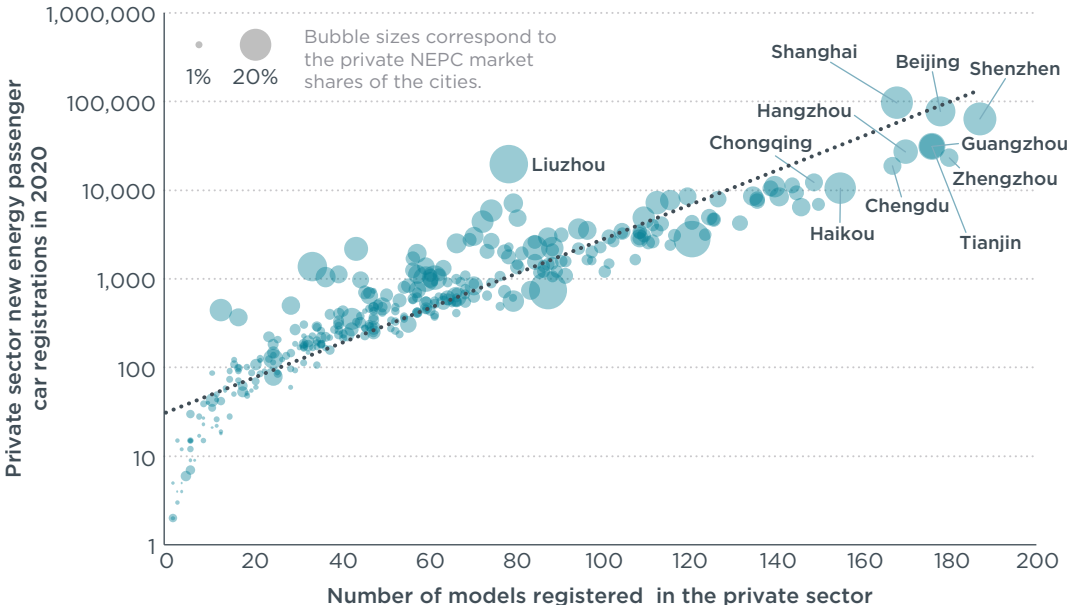


Figure 37. The number of new energy passenger car models registered in private sectors in 338 cities, 2020.

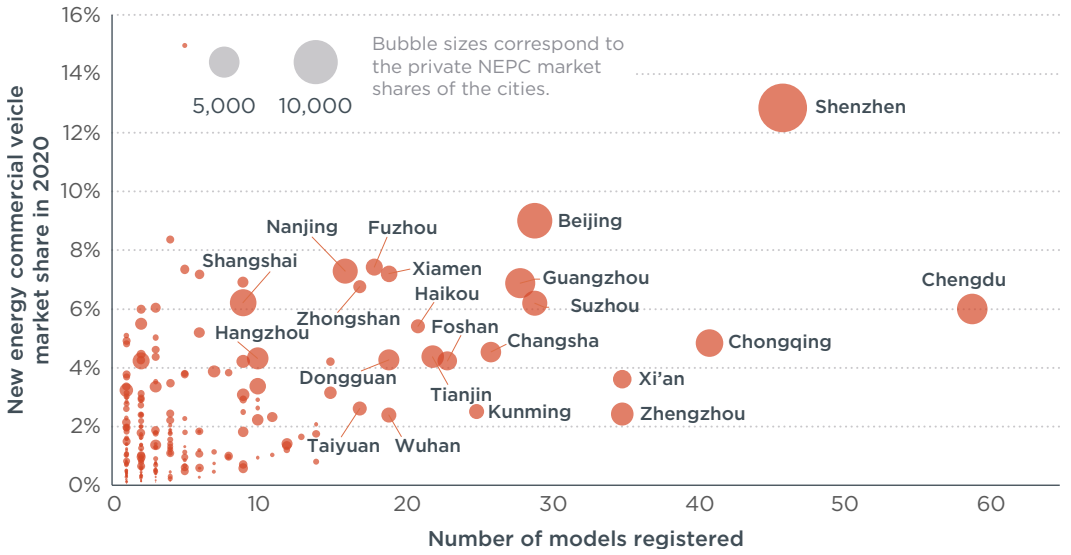


Figure 38. The number of new energy commercial vehicle models registered in 226 cities, 2020 (some cities did not have any registrations and were therefore excluded from our analysis).

4.3. POLICY DRIVERS

Many cities developed their own strategies and action plans to advance NEV uptake following central and provincial government guidelines. Some cities created dedicated NEV development plans, but others embedded NEV targets in local environmental, transportation, or industrial development plans. These plans usually included NEV deployment targets and infrastructure targets, and some cities included specific targets for different NEV fleets, such as government fleets, taxis, and urban logistics vehicles. Charging infrastructure targets were usually set in terms of indicators such

as the number of chargers, vehicle-to-charger ratio, and average coverage/density of chargers in a given service area.

Cities adopted a wide range of incentives to stimulate NEV purchase, and these were in addition to the tax exemptions and NEV subsidies applied nationally. Among the most common financial incentives for private consumers were one-time upfront subsidies and those during the use phase. Upfront subsidies included those provided at time of purchasing of a new NEV, when replacing a conventional vehicle with an NEV, and subsidies for purchasing private home chargers. Financial incentives during the use phase include free parking or reduced parking fee, reduced fee for charging, and more.

As central purchase subsidies phased down, more and more cities adopted non-financial incentives with the aim of providing convenience for NEV consumers. These include vehicle registration/license plate privilege, road access privilege, dedicated NEV parking spaces, and support for public charging infrastructure. Vehicle registration and road access privileges appear to have been crucial drivers of NEV uptake. With these, cities impose an annual vehicle registration quota to reduce urban congestion and air pollution and give easier registration privilege to NEVs. Similarly, some municipalities restrict certain vehicles from traveling on certain roads or in certain areas during certain times (e.g., weekday rush hours or on high-pollution days), while providing preferential access to NEVs.

Fleets are a key target for electrification under China's goals. More and more cities are providing specific incentives to certain types of fleets, such as taxis and ride-railing and rideshare vehicles; urban logistics vehicles; transit buses; and utility vehicles such as sanitation and postal vehicles. Common incentives include upfront purchase subsidies, subsidies during the use phase, replacement subsidies, low- and zero-emission zones, and road access privileges. Slightly different from the purchase subsidies for private consumers, there are usually mileage requirements that commercial fleets must meet to receive full subsidies; these are partially distributed at the time of purchase and the remainder is distributed in subsequent years after operation is verified. Subsidies during the use phase could include one-time usage subsidies, charging fee subsidies based on electricity used, and others that aim to support the operation of NEV fleets. Road access privileges have also been provided for centain fleets, where NEVs enjoy preferential access to certain areas during certain times when conventional fuel vehicles are restricted. This has been gaining popularity to promote new energy urban logistics vehicles in particular. In addition, some cities established low-emission zones where only new energy urban logistics vehicles are allowed at all times.

Since China's hazardous air pollution episode in 2013, environmental policies have been playing an increasing role in driving uptake of NEVs. The *National Air Pollution Prevention Action Plan* in 2013 (often called Air Quality Ten Principles) highlighted the boosting of NEVs (Nan, 2013). Successive policies, the *National Plan of Blue-Sky Defense* and *Action Plan for Battle Against Diesel Truck Pollution* (aka National Clean Diesel Action Plan), set both particulate matter concentration reduction targets and electrification share targets for specific fleets in key cities for 2020. Many cities struggling with air pollution or those that simply want to be proactive in pursuing world-class air quality have developed their own versions of these plans, and these further enhanced measures like promoting NEVs.

Figure 39 shows the air quality improvement, specifically change in $PM_{2.5}$ concentration in Chinese cities and the corresponding deployment of NEVs in the same time period. Due to data availability, we could not display the NEV share of the market at city levels on the x-axis, which is a more appropriate indicator for this analysis. Cities like Beijing, Shenzhen, Shanghai, Guangzhou, Hangzhou, and Tianjin, where road transportation is the source of a significant portion of the local air pollution, were most vigorous in promoting NEVs and gained substantial improvement in local air quality (in terms of

$PM_{2.5}$ concentration) in 2020 compared to 2015. Cities that made slower electrification progress but have similar problems with emissions from transportation could consider utilizing more NEVs as measure to improve local air pollution.

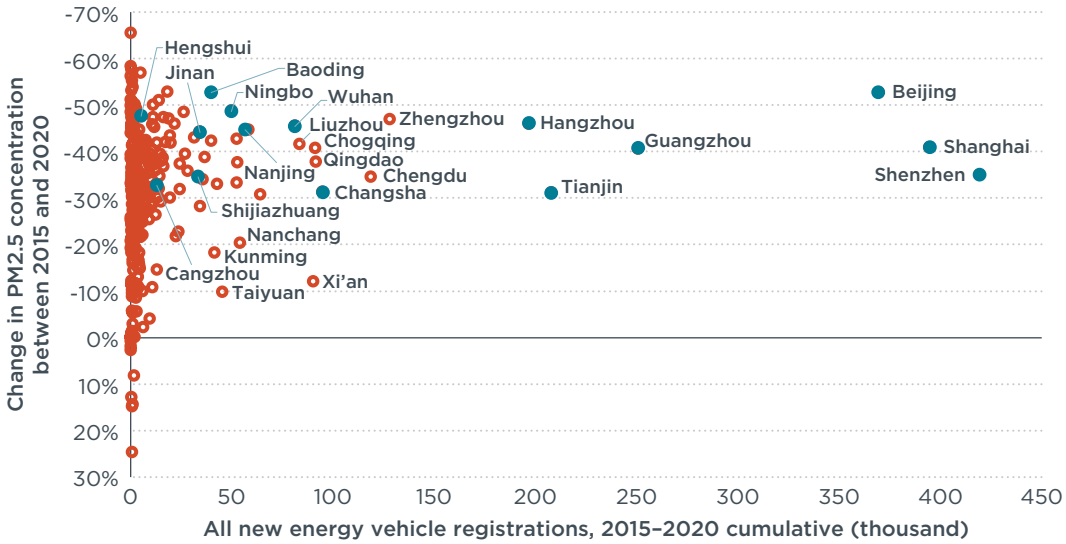


Figure 39. Change in $PM_{2.5}$ concentration and cumulative new energy vehicle registrations, 2015–2020.

*Blue dots indicate cities where transportation sources were significant urban $PM_{2.5}$ contributors. Source: China Mobile Source Environmental Management Annual Report, 2019 (MEE).

Table 2 highlights key policy instruments in the various NEV leading cities analyzed in the previous sections.

Table 2. Summary of policy tools and selected city cases

Policy/approach	Vehicle type	Policy type	Selected cities	Policy description
Dedicated NEV development plan	All	Target/plan	Shenzhen	Set a 5,000 new energy delivery truck target for 2020
Dedicated charging infrastructure plan	All	Target/plan	Nanjing	Install of public chargers every 1 kilometer, and one charger for every two new energy urban trucks registered
Fleet requirement in local clean air plan	Trucks	Target/plan	Handan	Required that clean transportation fleets be used by local iron companies
Purchase and use subsidies	Cars	Fiscal	Changsha, Zhengzhou, and Shenzhen	Temporary purchase and use subsidies to boost local car consumption, in response to COVID-19
Operation subsidy	Heavy-duty dump trucks	Fiscal	Shenzhen	Up to CNY 800,000 per truck if specific technical and annual mileage requirements are met
NEV replacement subsidy	All	Fiscal	Nanjing	Subsidy for replacing high-polluting cars with new energy ones
Charging subsidy	All	Fiscal	Shanghai, Tianjin, and Hangzhou	Reduced electricity fee or charging service fee
Charging facility construction/ operation subsidy	All	Fiscal	Shenzhen, Guangzhou, and Beijing	Allocated primarily on a per-kW basis and unit price varies between different technologies
Parking incentive	All	Fiscal	Liuzhou	Dedicated parking space and first-2-hours free street parking
License plate privilege	Cars	Nonfiscal	Shenzhen, Guangzhou, and Beijing	Annual quota on new car registration, but privileges are given to NEVs so that registration is easier than for conventional fuel cars
Road access privilege	All	Nonfiscal	Beijing, Tianjin, and Zhengzhou	Restricts most motor vehicles' access to certain areas at certain times, but exempts or reduces restriction on NEVs
Green logistics zones	Trucks	Nonfiscal	Shenzhen	Bans on high-polluting diesel trucks in designated urban areas
City cluster approach	Cars	Strategy	Liuzhou, Nanning, and Laibin	Similar small cities in a region form a cluster and adopt similar stimulus packages, such as Guangxi mode

5. CONCLUSIONS AND RECOMMENDATIONS

By analyzing NEV deployment in Chinese cities from 2015 to 2020, this study identified the leading city-level markets for passenger cars and various types of commercial vehicles. The top 30 city markets were home to nearly 70% of all new NEV registrations in 2020. Our primary findings are as follows.

For passenger cars:

- Tier 1 and New Tier 1 cities continued to play a pivotal role in driving the market, but NEV growth in Tier 2–5 cities gained traction. NEPCs sold in smaller cities reached 42% of total sales in 2020, doubling their representation as compared to 5 years earlier.
- Consumer preferences varied widely across different city tiers. Medium-size, longer-range, higher-end NEPC models dominated the markets of larger cities, while more affordable, mini-size models were most prevalent in small cities. The average electric range of BEVs in Tier 1 cities was 450 km, and it was about 400 km in New Tier 1 cities; 370 km in Tier 2 cities; and then approximately 280–300 km in the smallest city tiers. A similar pattern was observed for battery capacity. The top-selling vehicle model in Tier 1 and New Tier 1 cities was the Tesla Model 3, and in the other city tiers, it was the Wuling Hongguang Mini EV.
- Brand diversity of NEPCs in city markets increased dramatically from 2015 to 2020, and manufacturers sold to more markets beyond their home markets in 2020 compared with 2015. This suggests that local market protectionism was largely rectified.
- Despite different development paths and strategies, all kinds of cities, from large, affluent ones to smaller and less-resource-rich ones, can successfully promote electric mobility.
  - Megacities like Beijing, Shanghai, Guangzhou, and Shenzhen offered various forms of fiscal incentives, including purchase or operational subsidies, reducing parking fees, and charging subsidies, and non-fiscal incentives such as registration and road access privileges. These cities also often invested more than others in building a convenient charging network for urban NEV owners.
  - Smaller cities, meanwhile, developed unique NEV development patterns and some proved to be as successful as the megacities in NEV market penetration. City clusters in Guangxi focused on promoting their local car brand, Wuling Hongguang. The county-level city of Ningde, the manufacturing base of the world's leading NEV battery producer CATL, leveraged its great advantage in battery manufacturing and focused on building a complete supply chain. Hainan province adopted an ambitious electrification roadmap for road vehicles to create a first-class business environment compatible with its new strategic positioning as a regional free trade zone, and that led to NEV success in its major cities of Haikou and Sanya.

For commercial vehicles:

- Heavy passenger commercial vehicles (mostly city buses and coaches), and urban logistics vehicles dominated the market beginning in 2018. These two broad vehicle categories represented 90% of NECV registrations in 2020. Heavier trucks only began to emerge in 2018 after the launch of major environmental campaigns. Cities such as Shenzhen, Yangquan, and Xuzhou were good exemplars for electrifying dump truck fleets via cooperative efforts from local governments and business enterprises.
- NEV models for all commercial vehicle types considered—urban logistics vehicles, dump trucks, tractor trucks, buses, and coaches—were widely available, and they ranged from a few hundred models for buses to a few dozen for the heaviest tractor trucks.

» For the commercial truck segments, besides the unrivaled NEV market records set by Shenzhen, we observed emerging leading city markets of new energy urban logistics vehicles in Central Eastern (e.g., Nanjing) and Southwestern China (e.g., Chengdu), and for new energy dump truck and tractor trucks in Central and Northern China (e.g., Beijing, Yangquan, and Handan).

» For the city bus segment, most cities approached 100% NEV registrations in 2020. For the coach segment, Guangzhou deployed over 300 NEVs, and the market share of coach NEVs in seven cities exceeded 20% in 2020.

» Environmental policies played a pivotal role in driving the new energy truck market. Most leading cities of new energy trucks were in the key regions identified in the *National Plan of Blue-Sky Defense*. Some of the policies set direct requirements on the deployment of new energy vehicles: The *Action Plan for Battle Against Diesel Truck Pollution* required that 80% of new vehicles in the key regions use new or clean energy. Though this applied to heavy, polluting industries, other cities included provisions requiring the use of clean vehicles as part of a compliance package intended to reduce emissions across entire industries. One example is Promoting an Ultra-low Emission Steel Industry. In addition, these requirements spurred innovative local policies and initiatives such as low-emission zones and green multimodal collaborations and helped create a market for zero-emission trucks.

We also identified a few broad areas where China could increase its investment and policy focus in the coming years to make more headway in NEV deployment.

» *Urban and regional freight*. Cities and provinces still rely heavily on internal combustion engine vehicles for cross-region freight delivery and there is immense potential to utilize new energy trucks to fulfill local and regional freight transportation needs. The transition to electric is ripe for urban logistics vehicle fleets in terms of model availability, successful demonstrations from early movers, the presence of robust policy tools, and cost.

» *Northwestern and northeastern submarkets* are relatively underdeveloped. In these regions, long stretches of cold weather might present some challenge but need not be any deterrent to NEV ownership. Cities in these regions might consider longer-range models with appropriate thermal control, especially models that have already been shown to perform well in cities with similar but less frequent cold weather conditions, such as Beijing, Tianjin, and Changchun.

» *Tier 3–5 cities*. The accelerated urbanization and modernization process in small Chinese cities and towns will drive huge car demand. With proper policies and sufficient model availability, these cities can release massive potential for new energy vehicles.

» *Equity of clean air*. Although passenger and freight transportation are significant sources of urban and regional air pollution, consumers in polluted cities and regions cannot always afford electric vehicles. Favorable policies such as fiscal incentives are therefore needed to tilt the market toward NEVs in these regions. Note, too, that in Western China, where hydropower is abundant, NEVs will be closest to net-zero carbon emissions on a life-cycle basis.

The successful experiences from leading NEV cities in China can be a guide for other cities with similar local contexts within China, or elsewhere in the world. National governments around the world can also benefit from this analysis. With this in mind, our high-level takeaways are:

» China can aim higher with NEV deployment targets for passenger cars and commercial vehicles. Consider referring to 2020's leading NEV city markets for each vehicle segment for the 2025 national NEV targets, in other words, 30% NEV share

for new passenger cars, 60% for urban logistics vehicles, 50% for coaches, 10% for dump trucks, 7% for tractor trucks, and so on.

- As national-level subsidies phase out in China, cities can still exploit a wide range of indirect incentives to help bring their NEV markets to maturity, and these include dedicated parking spaces, registration privileges, and preferential road or lane access. Instead of large, upfront purchase subsidies, cities can also consider smaller, use-based incentives such as utility rate discounts, parking and charging fee reductions, and zero-emission zones.
- The market will embrace vehicle models that truly meet local reality and needs. Mini-size cars such as the Wuling Hongguang Mini EV, at a fraction of the price of a Tesla, cannot deliver the same 500 km electric range but are sufficiently affordable, functional, and convenient to replace the gasoline motor scooters that used to be the dominant transport mode of lower-income consumers.
- Government-automaker partnerships are especially important for gaining an understanding of the precise local needs and strategizing model rollout and complementary policies.
- Electrification can be a win-win strategy for local economic development, carbon emissions mitigation, and improving air quality in cities with an established automotive industry, supply chain, or a plan to nest one. Cities should invest in the technologies of the future, such as NEVs, rather than the technologies of the past.
- The decision-making bodies of cities can form multi-agency collaborations and craft coherent policy packages to promote NEVs most effectively. The agencies each have their unique power and authority, and with adequate and strategic planning, their actions can work together to increase NEVs in transportation. Environmental bureaus might require high-polluting industries to use clean transportation equipment and designate low- or zero-emission zones; transportation bureaus could favor NEVs for road access or registration; industrial bureaus might set NEV development targets as part of local economic development plans, and so on. There is a strong need for coordinated policy development that provides market guidance and promotes ecological sustainability.

Finally, although outside the scope of our analysis, we recommend policies to avoid or shift private, motorized travel to naturally zero-emission mobilities such as walking and biking where possible in cities and population-dense areas.

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