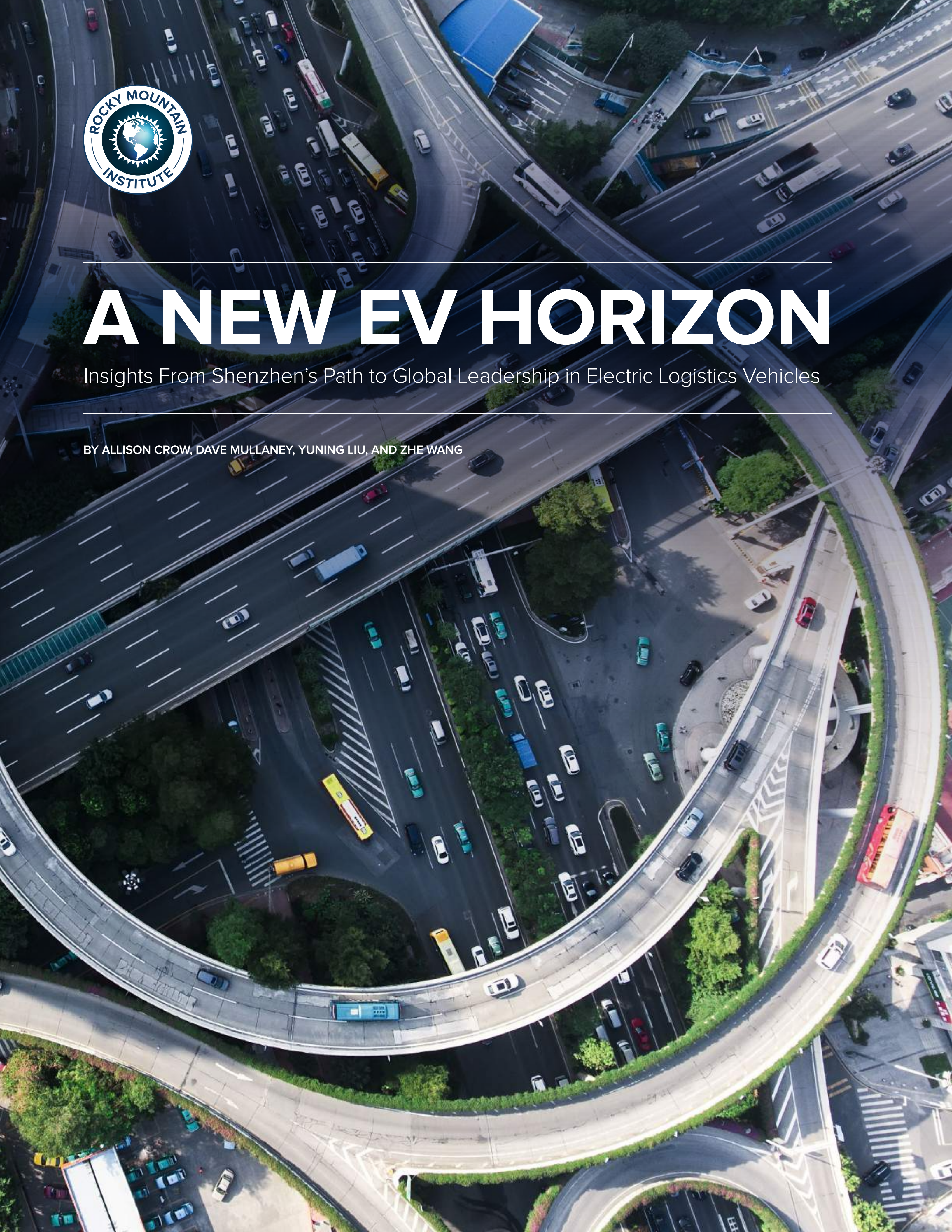

A NEW EV HORIZON

Insights From Shenzhen's Path to Global Leadership in Electric Logistics Vehicles

BY ALLISON CROW, DAVE MULLANEY, YUNING LIU, AND ZHE WANG

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ABOUT US

ABOUT ROCKY MOUNTAIN INSTITUTE

Rocky Mountain Institute (RMI)—an independent nonprofit founded in 1982—transforms global energy use to create a clean, prosperous, and secure low-carbon future. It engages businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. RMI has offices in Basalt and Boulder, Colorado; New York City; the San Francisco Bay Area; Washington, D.C.; and Beijing.

ABOUT THIS RESEARCH

Eliminating carbon emissions from goods transport is one of the key challenges to the transition to a low-carbon global economy. A critical element of decarbonizing goods movement is transitioning away from the use of fossil fuels in favor of electricity. Over the last several years, large reductions in battery costs and commensurate gains in battery energy density have brought electric delivery vehicles into the range of economic viability, and the use of electric vehicles (EVs)—particularly in urban delivery—now represents a compelling near-term opportunity.

In response to the more attractive financial returns offered by delivery EVs, their use has taken off globally. In China, with strong policy support, the use of electric delivery vehicles has grown explosively. At the same time, in the United States and Europe, leading companies have deployed small numbers of EVs into their daily operations and are poised to rapidly increase deployment rates. Even in less economically developed countries, such as India, leading companies are taking the first steps in commercial EV deployment as well, suggesting that the use of those EVs will not remain confined to rich countries.

With policy support in Shenzhen, China, making EVs commercially viable, Rocky Mountain Institute (RMI) is working to overcome additional barriers and accelerate adoption to achieve a 100% EV goal, and to share insights from the experience in Shenzhen globally, including elsewhere in China, India, and the United States. Our research collaboration with the City of Shenzhen has taken on one of the most important barriers to the accelerated adoption of EVs in urban delivery: how to effectively provide them with charging infrastructure.

To answer that question, this paper uses a unique data set with complete driving records of over 10,000 electric delivery vehicles in the city of Shenzhen, supplemented by dozens of interviews with the companies that own and operate those vehicles, to analyze in unprecedented detail how those trucks are charging and what can be done to improve the charging system. To the authors' knowledge, this is the most complete documentation and analysis of the operational and charging patterns of urban electric delivery vehicles ever undertaken at the city level. It will serve as a foundation for ongoing, data-driven research to enhance the effectiveness of policymaking regarding commercial EV charging, and to better position the private sector to efficiently invest in the growth of the system. We hope that this research will support Shenzhen as it continues to be the global leader in the use of EVs for urban delivery, and other cities that seek to follow the path that Shenzhen has pioneered.

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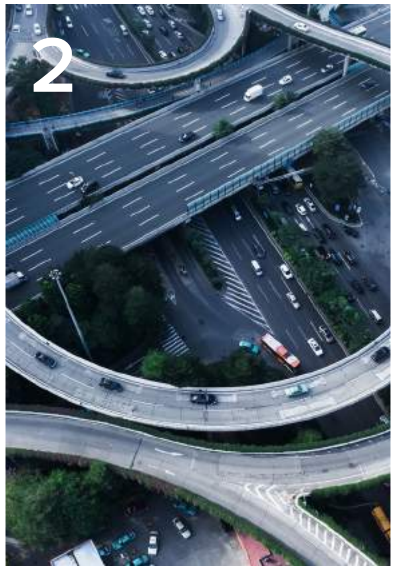


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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

Shenzhen, China, is a global leader in the deployment of electric vehicles (EVs) for urban logistics. In this paper we analyze and share Shenzhen's experience with electric logistics vehicles (ELVs) with the hope that it can accelerate the deployment of electric vehicles and charging infrastructure in three ways:

- First, by supporting Shenzhen as it seeks to further refine policies to support the full electrification of urban logistics, especially with regard to the deployment of charging infrastructure

- Second, by enabling other cities in China, which operate in a policy and investment climate similar to Shenzhen's, to rapidly follow the path to electrification that Shenzhen has pioneered

- Third, by bringing the story of Shenzhen to cities globally, which typically operate in very different policy and investment climates than Shenzhen's, so that they can understand the types of challenges that logistics electrification can create, and craft their own solutions to those problems

From the beginning of 2015 to the end of 2018, Shenzhen's fleet of electric logistics vehicles, vans, and light/medium trucks expanded from 300 to approximately 61,857.[1]

On the commercial side two key factors have supported the rapid growth of the vehicle market:

- Strong model availability, with over 45 brands delivering electric urban vehicles at acceptable price points and operational performance

- The emergence of leasing companies that bundle the provision of vehicles, charging, maintenance, and, at times, even drivers for a flat monthly or annual fee

Similarly, on the policy side three key factors have supported rapid vehicle deployment:

- **Vehicle purchase subsidies and operational subsidies** that create near upfront cost parity between electric logistics vehicles and their internal combustion (ICE) competitors

- **Exemptions from urban access restrictions** that allow electric vehicles to enter the city at times during which and to drive on roads on which ICE logistics vehicles are banned

- **Strict emissions requirements** on the registration and use of ICE logistics vehicles

During the 2015–2018 period, EV charging infrastructure also grew rapidly, with approximately 40,600 chargers installed through 2018.[2] Part of that growth was driven by demand from the rapidly expanding population of electric vehicles, but charging infrastructure growth also benefitted from generous policy support, including:

- **Subsidies** for the construction of charging infrastructure

- **Mandates** from the municipal government on the number of chargers installed and the districts in which they are to be installed, which has accelerated the approval process from the grid

- **Low industrial electricity prices** for charging stations and regulated service fees collected by charging stations that provide predictable revenue on every charge session

Despite the rapid growth in the number of chargers, the recent expansion of electric logistics vehicles has challenged the ability of Shenzhen to provide sufficient charging capacity. This has produced several pain points for owners and operators of logistic vehicle fleets, charging stations, and China Southern Power Grid. Those pain points include:

- A mismatch in the location of the demand for charging service and the location of the majority of the charging infrastructure. Typically demand for charging services is in central areas of the city where trucks operate, while the majority of chargers are in the city periphery or more suburban areas.
- A mismatch in the geography of demand for charging services, again typically in more central areas of the city, and the locations where grid capacity for charging currently exists or could be added at low cost, again typically in more suburban areas.
- A strong preference for fast charging, which, while convenient for drivers, requires significant investments in the grid, especially in more dense urban areas.
- A strong preference for daytime charging, which adds to peak loads and requires distribution grid upgrades.
- Variable utilization of charging stations, with high-use charging stations experiencing overcrowding and queuing and charging stations that are less conveniently located struggling to produce acceptable returns on investment.
- Parking policies that allow for ICE vehicles to park at spaces equipped with a charger.
- A large number of chargers that are either not functional or not available for use by logistics users.
- Difficulty in knowing which chargers are occupied and which chargers are available for use.
- In certain circumstances, difficulty making payments for charging services.

In order to address those pain points, Shenzhen can implement a portfolio of solutions that includes:

- Planning processes that incorporate data on the geography of charging demand into the planning process for charging station deployment
- Pricing strategies that seek to influence the distribution of charging demand across time and location to create an efficient balance between driver convenience and cost to the grid
- Colocation of ancillary services, such as restaurants and shops, that enable drivers to conveniently charge at times of low productivity in locations that are friendly to the grid
- Updating of parking regulations to ensure that parking spaces equipped with chargers are not occupied by ICE vehicles

- Adopting strategies to enable and incentivize slow charging at night
- Creating a single portal with information about charger location and availability to enable drivers to select the most convenient charger
- Evaluation of forward-looking strategies for charging, including V1G and V2G smart charging strategies[i]

As a global leader in electric vehicle deployment, Shenzhen has documented its experience in significant detail by requiring the collecting and sharing of granular electric vehicle data. Shenzhen's willingness to pioneer the electrification of urban logistics as well as document and share its experience creates a clear path for other cities in China to follow. This process will help other cities follow in the footsteps of Shenzhen, and even accelerate their own paths to significant deployment of electric vehicles.

[i] V1G is a single-direction, controlled charging technology between the grid and ELVs. V2G is a bidirectional interaction technology between vehicles and the grid.

1 INTRODUCTION

INTRODUCTION

BACKGROUND

With rapidly falling battery prices and rapidly increasing availability of electric vehicles (EVs), the electrification of urban transport has become an area of focus for many cities globally. Most of the attention of electrification of urban transport has fallen on passenger travel. However, another subsector of urban transport, urban logistics, is also ripe for electrification and can act as a high value first mover in overall electrification of urban mobility. The electrification of urban logistics through the deployment of electric logistics vehicles (ELVs) should be a high priority target for cities for several reasons:

- First, the trucks used in urban delivery are typically diesel powered, which is a major contributor to urban air quality problems.

- Second, those trucks typically consume more energy and emit more carbon than passenger vehicles. In Shenzhen, ELVs drive approximately 17,000 km per year, whereas passenger cars travel approximately 10,000 km per year.[3] Because of the higher utilization and lower fuel economies, the carbon impact of electrification of each logistics vehicle is approximately twice that of a passenger vehicle.

- Third, because of their high utilization and fuel consumption, electrification of urban trucks typically has a quicker capital recovery period than passenger cars. This superior value proposition lowers the need for subsidization to create demand.

- Fourth, vehicle preferences in freight are primarily driven by economic factors, whereas passenger vehicle selection is driven by a complex array of behavioral factors. This makes the incentive package for freight vehicles easier to design and the results of those incentive packages easier to predict.

- Fifth, because people are risk averse when it comes to changes in their personal travel patterns, regulators are typically more willing to make aggressive moves in the electrification of freight vehicles than passenger vehicles.

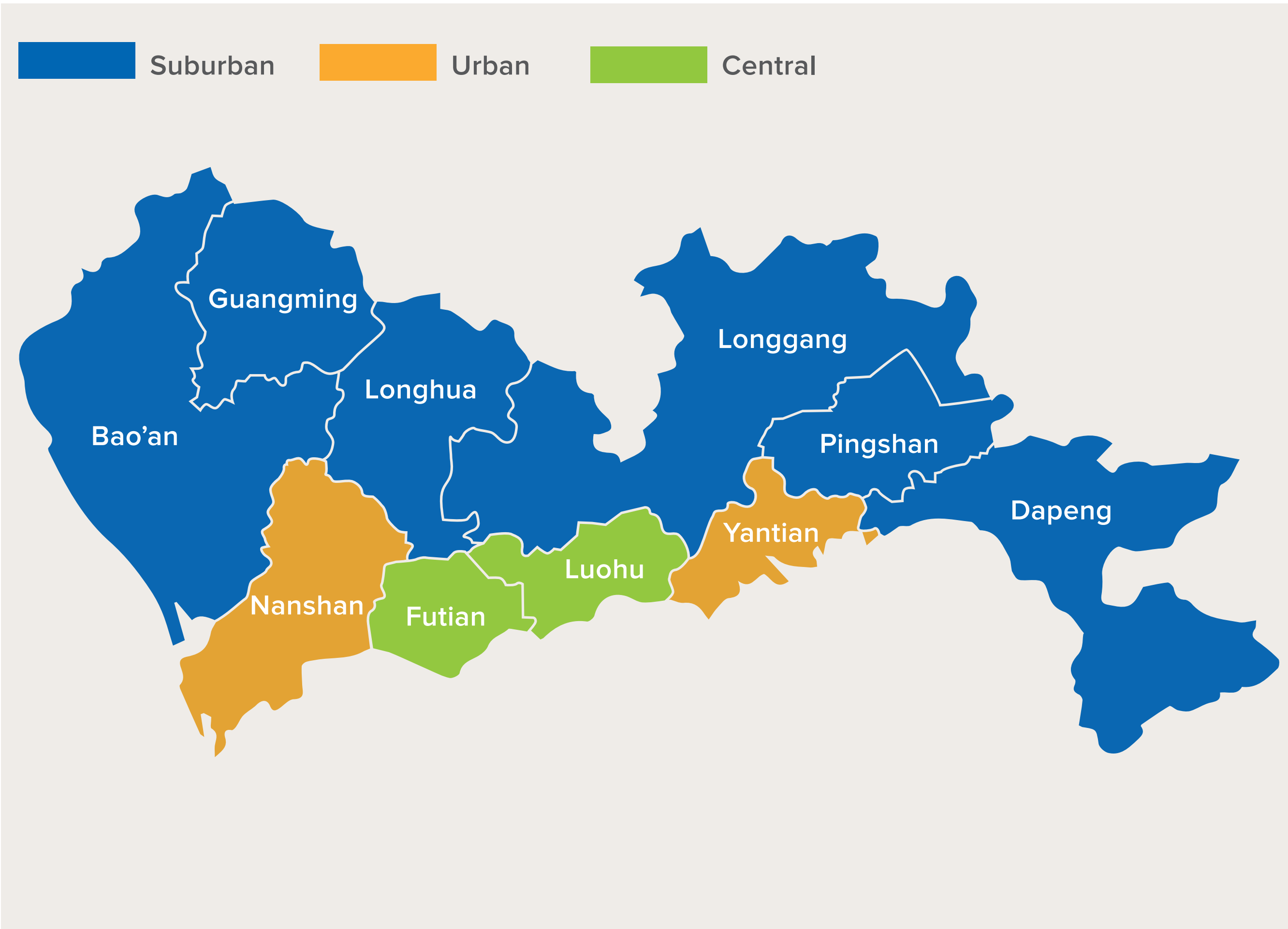
- Sixth, urban fleets, including ELVs, primarily use public fast charging and can be anchor tenants for public fast-charging stations. The electrification of those fleets can guarantee a sustainable rate of return for charging station operators and support the growth of a fast-charging network. This is important for the overall electrification because, while personally owned EVs will likely be charged using slow charging at the operator's home or place of work, drivers often demand a mature public fast-charging network to alleviate range anxiety. By supporting the ubiquitous deployment of fast charging, electrification of urban logistics can accelerate the universal deployment of EVs for urban mobility.

Due to the above factors, rapid deployment of ELVs has been the focus of the vehicle electrification effort in China.[4] In 2017 alone, 152,000 new energy logistics vehicles, primarily electric, were sold in China. While this number is large compared with sales in other countries, it is still a relatively small share of the addressable market of 3 million vehicles.[5] This suggests that there is substantial room for China to accelerate the deployment of ELVs nationally.

Shenzhen, a city in southern China's Guangdong province directly bordering Hong Kong, has been at the vanguard of ELV adoption globally. Shenzhen is home to over 12 million people and has the third-largest economic output of any Chinese city, behind Shanghai and Beijing. It is composed of 10 administrative districts, with suburban areas in the north and east parts of the city and dense urban agglomerations primarily in the south and central-west areas of the city (Exhibit 1).

EXHIBIT 1

Map of Shenzhen and Its Districts



Source: RMI Analysis

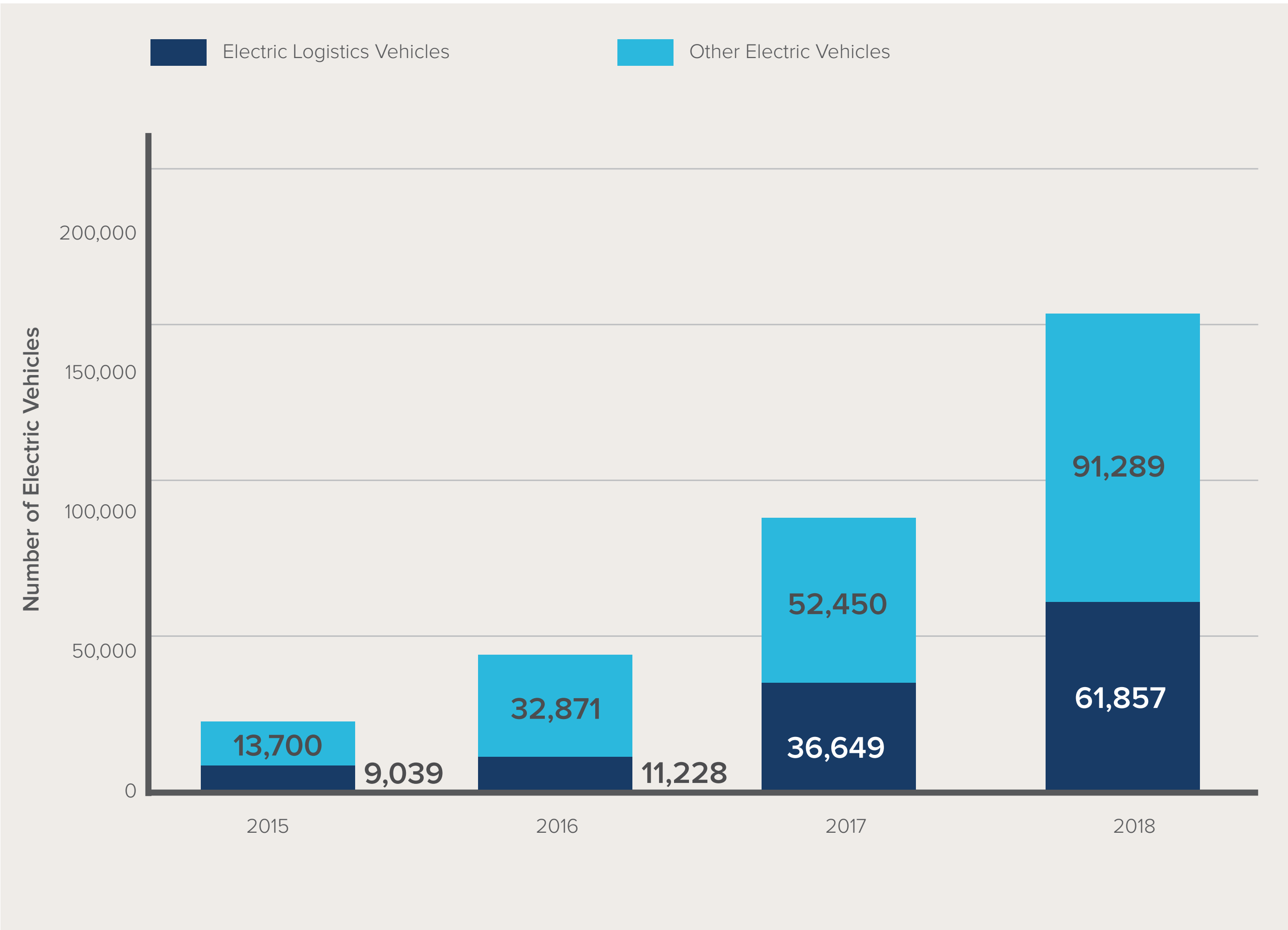
At the beginning of 2015, approximately 300 operative ELVs were registered in Shenzhen.[6] By the end of 2018, that number had grown to 61,857, accounting for 24% of all the EVs registered in the city (Exhibit 2).[7] This explosive growth has led Shenzhen to become the world's largest market for ELVs, forcing the logistics industry, the electricity grid, and municipal policymakers to rapidly craft new business and regulatory models.

OBJECTIVES

In this paper we introduce the story of logistic vehicle electrification in Shenzhen, giving an overview of market growth, business models deployed, and regulatory changes to support that market. In combination with extensive interviews of stakeholders in Shenzhen, we use a robust data set to analyze ELV driving and charging patterns and their associated pain points, and suggest potential solutions to those pain points. The purpose of this analysis is to advance logistics electrification in three ways:

EXHIBIT 2

Shenzhen Electric Vehicle Population 2015–2018[8]



Source: Diandong Alliance, *Shenzhen Doubled the New Energy Vehicles Number in 2016*

- Support Shenzhen as it seeks to further refine policies to support the full electrification of urban logistics, especially with regard to the deployment of charging infrastructure
- Enable other cities in China, which operate in a policy and investment climate similar to Shenzhen's, to rapidly follow the path that Shenzhen has pioneered
- Bring the story of Shenzhen to cities globally, which typically operate in very different policy and investment climates than Shenzhen's, so that they can understand the types of challenges that logistics electrification can create, and craft their own solutions to those problems

ANALYSIS APPROACH

As Shenzhen has grown its ELV population, it has documented its experience in extraordinary detail due to mandates on data collection and sharing from those vehicles. Every electric truck and van in Shenzhen is equipped with a telematics box that reports GPS coordinates, battery data, and engine data at 30 second intervals to an aggregated new energy vehicle data monitoring platform. The analysis included in this report is based on a data set comprised of approximately 10,000 electric trucks and delivery vans collected from January 2018 through December 2018, resulting in over 2 billion individual readouts.

This analysis utilized four key sources of data: GPS coordinates, state of charge (SOC), odometer readings, and time stamps. Vehicle speed and distance traveled were understood using GPS, odometer readings, and time to map and characterize the movement of the ELVs. Changes in SOC over time provided insight into charging patterns and helped to characterize why the vehicle was stopped and whether to charge or to provide services. For approximately 40% of vehicles in the data set, detailed information about vehicle model and specifications are contained in the data set. For those vehicles, 55.5% of the vehicles are known to be light- and medium-duty trucks, whereas 44.5% are vans.

2 VEHICLE AND CHARGER POLICY CONTEXT

VEHICLE AND CHARGER POLICY CONTEXT

Policy support has been a key driver of ELV adoption in Shenzhen. The following section summarizes the policies implemented in Shenzhen and the implications on ELV deployment to inform policymaking in other cities and regions. In the Shenzhen market, policymakers have implemented four types of policy to spur rapid adoption of ELVs and associated charging infrastructure:

1. **Subsidies** lower the upfront cost of ELVs compared with similar ICE vehicle alternatives and support private deployment of charging infrastructure.

2. **Preferential road access** for ELVs increases their utilization and, therefore, revenue.

3. **Preferential electricity rates and fee exemptions** for charging operators, and therefore ELV operators, lower fuel costs.

4. **Mandates and targets** at the city and district level for the number of chargers within a specified timeline support growth of the charging network.

The combination of these policies has led to enhanced margins supporting ELV profitability and uptake and incentives to choose ELVs for goods delivery over comparable fossil fuel-based vehicles.

ELV SUBSIDIES

ELV subsidies in Shenzhen target the purchase cost differential between ELVs and traditional ICE logistics vehicles. Beginning in 2013, the Development Research Center of the State Council, the Ministry of Industry and Information Technology, and the Ministry of Finance provided subsidies, while subsidies were also offered at the local level by the Shenzhen municipal government.

In Shenzhen the value of ELV operational subsidies is based on battery capacity and has been calibrated to create near purchase price parity between ELVs and ICE delivery vehicles. The post-subsidy purchase cost of an electric van is 77,800 RMB compared with 62,670 RMB for a similar gasoline vehicle, and 160,000 RMB for an electric light-duty truck versus 144,598 RMB for a comparable diesel model. With lower operating costs, ELV capital recovery periods are typically one to one and a half years.

Starting in 2013, the national subsidy was 2,000 RMB/kWh with local governments, including Shenzhen, often matching the national subsidy. As prices of ELVs have fallen, those subsidies, especially the municipal component, have fallen to keep ELVs near cost parity with diesel trucks (Exhibits 3 and 4). On March 26, 2019, the Ministry of Finance released the 2019 new energy vehicles purchasing subsidy standard, which reduced the national subsidy to 350 RMB/kWh and canceled the local subsidy and called for a full subsidy phaseout by 2020.

In order to incentivize the utilization of ELVs, Shenzhen leads as the first city in China to carry out operational subsidy standards. Fleets that own 300 or more trucks and at least 100 ELVs can earn the subsidy if each truck has a mileage of more than 15,000 km. The subsidy is based on battery size, and will not exceed 75,000 RMB in a consecutive three-year period.

EXHIBIT 3

Subsidy for 50 kWh ELV (RMB)

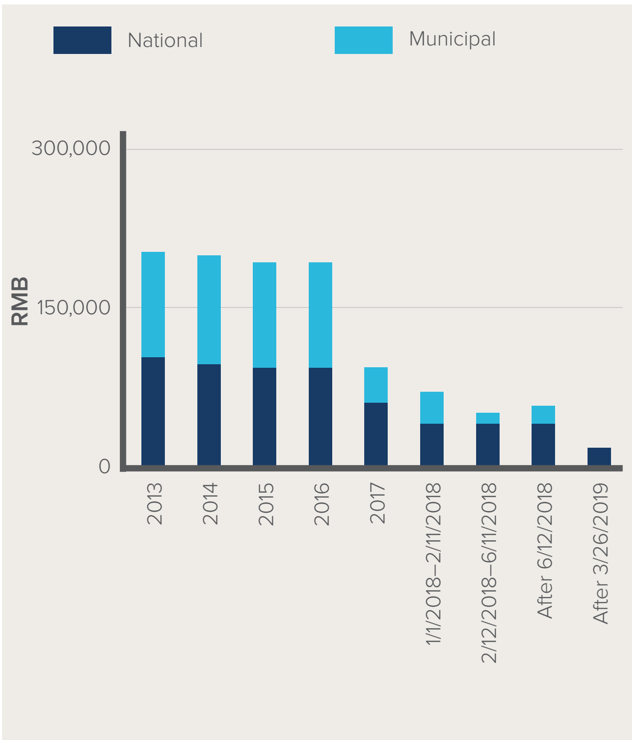
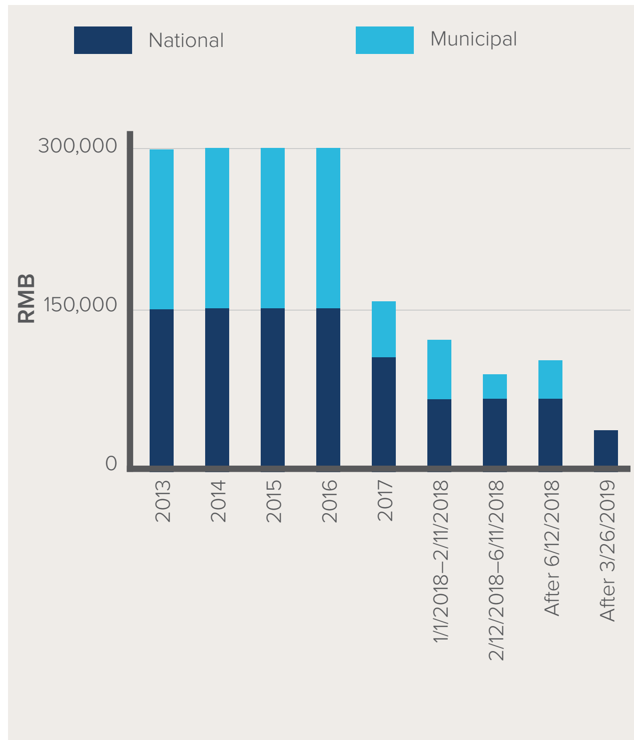


EXHIBIT 4

Subsidy for 105 kWh ELV (RMB)



Source: Shenzhen New Energy Vehicles Promotion and Application Financial Supporting Policy 2015–2018

CHARGER SUBSIDIES

Shenzhen's subsidy portfolio is not confined to vehicles; it also extends to the construction of charging stations. The charger subsidy portfolio has evolved over the years from a broad subsidy available to anyone to a more targeted subsidy that seeks to encourage large charging providers to rapidly deploy aggregated charging infrastructure for fleet vehicles (see Exhibit 5). From 2013 to 2015, the municipal government provided a subsidy to charging facilities equivalent to 30% of the facility cost.[9] In 2016, the subsidy regime shifted from a share of total investment to fixed payment per unit of installed capacity, and an eligibility requirement was added to restrict the subsidy to large-scale players. In 2017, Shenzhen doubled the amount of the subsidy, providing 600 RMB/kW to DC chargers[10] and 300 RMB/kW to AC chargers.[11]

EXHIBIT 5

Subsidy for Charging Facilities in Shenzhen[12]

Year	Power Requirement	Subsidy Objective	Subsidy Amount
2013–2015		Investment in centralized charging facilities including stations, chargers, and equipment	30% of the total investment
2016	Cumulative charging power in Shenzhen of 8,000 kW or more	Provide DC and AC facilities for use by fleet vehicles: public buses, taxis, logistics vehicles, sanitation vehicles, leasing vehicles; AC facilities for others	300 RMB/kW for DC chargers 150 RMB/kW for AC chargers
2017	Cumulative charging power in Shenzhen of 8,000 kW or more	Same as in 2016	600 RMB/kW for DC chargers 300 RMB/kW for AC chargers
2018	Cumulative charging power in Shenzhen of 8,000 kW or more	Same as in 2016	600 RMB/kW for DC chargers 300 RMB/kW for AC chargers (>40 kW) 200 RMB/kW for AC chargers (<40 kW)

Source: Shenzhen New Energy Vehicles Promotion and Application Financial Supporting Policy 2015–2018

SUBSIDY ELIGIBILITY CRITERIA

For both vehicles and chargers, subsidy eligibility is contingent on compliance with technical and quality requirements as laid out in China's national, local, and industrial charger standards.

One eligibility criterion serves to drive investment in improved quality of ELVs available for sale. Specifically, policymakers have focused on increasing the energy density of batteries on trucks and increasing the efficiency of the trucks themselves. In 2018 a minimum battery energy density of 115 Wh/kg was required, up from 90 Wh/kg in 2017. Over the same time, the limit on power consumption per ton of loading capacity per kilometer driven was decreased by 38.5%. Furthermore, in the second half of 2018 a minimum battery range requirement of 150 km was added for municipal subsidy eligibility.

Operational requirements of the subsidy eligibility ensure that only legitimate operators are able to obtain the subsidy. They require that a truck travel a minimum of 15,000 km per year and that data from onboard telematics boxes be shared with a central data collection. These requirements allow the government to ensure that subsidized vehicles comply with the technical standards, and that subsidies are not being captured fraudulently with low-quality vehicles that are not actually used commercially, which had been an issue in previous policy rollouts.

For chargers, the standard regulates electric vehicle chargers' power and voltage output, expected operational life, safety, and flexibility (i.e., that the charger is suitable for various voltages and frequencies).[13] Also, similar to ELVs, all chargers are required to be connected to the Shenzhen New Energy Vehicle Charging Service Monitoring Platform to verify compliance with subsidy requirements.[ii] Finally, in an effort to spur consolidation within the highly fragmented charging industry, only operators that have cumulative charging station capacity of 8,000 kW or more (equivalent to approximately 160 fast chargers) are eligible for subsidies.

PRIORITY ACCESS FOR ELVS

Shenzhen strictly restricts the time and routes that ICE, particularly diesel, trucks may drive in order to manage the congestion and air pollution that those vehicles cause (Exhibit 7). Preferential road access rights permit ELVs in Shenzhen to operate on certain routes and at certain times that ICE trucks are banned (the only exception is certain portions of Shennan Boulevard, a heavily congested street in the central area that is closed to all truck traffic every day from 7:30 a.m. to 9:00 p.m.).[14] Priority access represents a significant advantage for ELVs in terms of operational efficiency and improved customer service.

EXHIBIT 6

Technical and Operational Standards for ELV Purchase Subsidy

Year	Battery Energy Density	Energy consumption per unit load for electric cargo and delivery vehicles	Nonpersonal user cumulative driving distance
2017	No lower than 90 Wh/kg	No higher than 0.5 Wh/km*kg	30,000 km
2018	No lower than 115 Wh/kg	No higher than 0.4 Wh/km*kg	15,000 km

Source: New Energy Vehicles Promotion Subsidy Plan and Technology Standards 2018

[ii] That platform is not yet operational but will generate very useful information on grid load and utilization rates once it is fully deployed.

EXHIBIT 7

Summary of Logistics Vehicle Access Restrictions in Shenzhen

Restriction	Description of restriction	ICE not registered in Shenzhen	China III ICE standard or below	China IV - China V Standard	China VI	Electric logistics vehicles
Daytime entry	Diesel trucks registered outside Shenzhen are banned from entering the city everyday between 7:00 a.m. and midnight.[15]	No	Yes	Yes	Yes	Yes
Exempt from odd/even driving restrictions	Diesel trucks registered in Shenzhen that are at or below the China III standard are only allowed to enter the city every other day, based on whether their license plate ends in an odd or even number.[16]	No	No	Yes	Yes	Yes
Qualified to register in Shenzhen	Shenzhen is no longer accepting registrations for China IV and V diesel trucks.	No	No	No	Yes	Yes
Permitted in green logistics zones	Diesel trucks registered in Shenzhen that meet or exceed the China IV standard are permitted daily entry but are banned in certain areas of the city called "green logistics zones."	No	No	No	No	Yes

Source: Shenzhen Trucks Road Restriction Policy Announcement 2017; Shenzhen Municipal Government 2018 "Shenzhen Blue" Sustainable Action Plans 2018

One particularly innovative priority access policy is the use of green logistics zones, which are similar to zero emissions zones but govern only logistics uses. They are a relatively new approach to the promotion of ELVs in Shenzhen, but a potentially impactful one. Beginning in July 2018, diesel trucks were banned from entering these zones all day, every day.[17] Green logistics zones are currently in a pilot phase. If successful, they will expand in area with the long-term target to reach full coverage of the city. The potential for expansion of these zones creates increased uncertainty for purchasers of ICE trucks, which further incentivizes purchase of ELVs.

In addition to route restrictions, Shenzhen also improves access for ELVs by providing free parking. In Shenzhen, all EVs, including ELVs, have one-hour free curbside parking in the city and two hours of free parking in city-owned parking lots, which reduces the cost of stopping to make deliveries and to charge.

These superior access rights for ELVs compared with their ICE competitors promote higher utilization and revenue generation and allow for better customer service for ELVs. As the vehicle purchase subsidy is gradually being phased out, the use of preferential access to promote the adoption of ELVs has increased in importance.

PRICING REGULATIONS

Currently, “concentrated” stations receive a preferential electricity rate. In order to qualify as concentrated, a charging station must have at least three chargers with a total capacity of at least 350 kW and have a minimum of a three-year contract with the parking lot where the chargers are located. The electricity price is set by Shenzhen Development Research Center such that all concentrated charging stations are able to purchase electricity at industrial and commercial rates, ranging from 0.17 RMB/kWh to 1.03 RMB/kWh, depending on the time of day and the voltage required. ELV charging fees include both a charging service fee and the cost of the electricity sold. Charging service fees are regulated at no more than 0.8 RMB/kWh, with typical costs of 0.5 RMB/kWh for slow chargers and 0.7 RMB/kWh for fast chargers.

Fee exemptions also reduce costs for charging station operators and users. All concentrated chargers that have been reported to grid companies are free from basic electricity fees.[18] Those basic fees range from 24–44 RMB/kW of capacity monthly and are typically used to pay for investments in and maintenance of grid infrastructure.

This pricing scheme has several effects on the market:

- First, it puts fast-charging stations at an advantage relative to stations with slow chargers because far fewer fast chargers are required to meet the concentrated charger 350 kW capacity threshold.

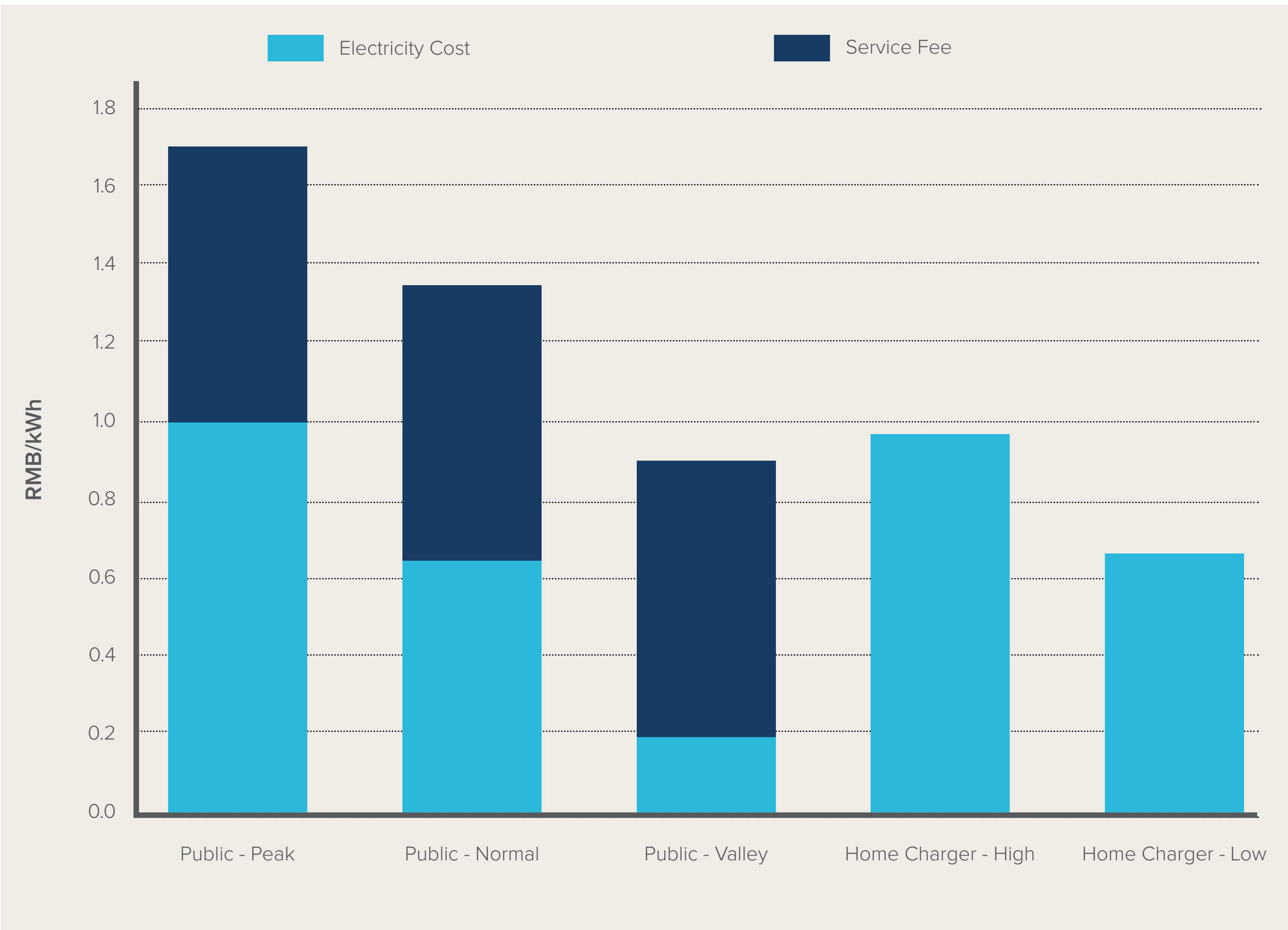
- Second, it disincentivizes ELV operators from installing chargers at their homes, where overnight charging would be viable. The price a user sees at public fast and residential slow chargers is quite similar—meaning that the convenience that fast charging provides is essentially free to the user, in spite of its greater grid costs. Residential electricity rates in Shenzhen are tiered based on overall usage, with costs ranging from 0.67 to 0.97 RMB/kWh (Exhibit 8, see appendix for details). Because ELV charging is a significant load, and the cost of electricity increases with total load, people charging ELVs at home are likely to experience the highest residential prices. Those prices are approximately equivalent to prices available at off-peak rates from public fast chargers even after the service fee has been included. That near price parity, combined with the capital investment of

7,000 to 10,000 RMB required to install a home charging station, make fast charging during valley price periods the most attractive option for drivers.

- Third, the price structure and the resulting parity between the price of fast and slow charging are significant contributors to the distribution of plug-in times.

EXHIBIT 8

Prices Seen by Users of Various Charge Facilities and Their Composition



Source: Guangdong Development and Reform Commission New Energy Vehicles Charging Electricity Rate 2018; Teld New Energy Co., Potevio New Energy Co., and Southern Heshun, Shenzhen e-Truck Charging Station Operational Status Survey and Investigation

TARGETS

In addition to subsidies and pricing structures, Guangdong provincial and Shenzhen municipal governments have set a series of specific targets for the future construction of ELV charging facilities in the city.

At the provincial level, three important targets have been formulated by policymakers. First, by 2020, 300 additional charging stations shall be completed exclusively for logistics and sanitation vehicles in the province.[19] Second, all newly built commercial buildings and public parking places shall reserve no less than 30% of proposed parking spaces for EV charging facilities.[20] And third, the province has planned to construct 108 pairs (one on each side of the road) of intercity highway fast-charging stations in 2018–2020.[21]

On the municipal level, the 2018 “Shenzhen Blue” Sustainable Action Plan mandated that Shenzhen will complete the construction of an additional 13,400 chargers by December 31, 2018. The mandate also included district-specific requirements to ensure balanced charging network development, including the construction of no fewer than 1,900 chargers in Bao’an and Longgang Districts each; no fewer than 1,300 chargers in Futian, Luohu, Nanshan, Longhua, Pingshan, and Guangming New District each; and no fewer than 900 chargers in Yantian and Dapeng New District.

3 KEY CHARACTERISTICS OF THE SHENZHEN ELV MARKET

KEY CHARACTERISTICS OF THE SHENZHEN ELV MARKET

To understand the market that Shenzhen and Chinese national ELV policy has created, we conducted market research, local stakeholder interviews, and analysis of detailed ELV telemetric data. With an understanding of the current market and how it developed from policy initiatives, further improvements can be made and potential implications for other cities and countries as ELV deployment is scaled can be understood.
There are seven key characteristics of the current Shenzhen ELV market:

1. **The market is highly fragmented with a large number of companies deploying ELVs in leasing models.**

2. **ELVs have moderate size batteries that comfortably support once-per-day charging.**

3. **ELVs deliver in understandable patterns in space and time based on key attributes of their services.**

4. **Available charging locations do not align well with ELV charging needs.**

5. **The charging station market, particularly for fast chargers, is growing rapidly and is highly fragmented.**

6. **ELV operators have a clear preference for fast charging.**

7. **ELV operators charge their vehicles strategically during breaks in their day.**

To continue to grow their markets, the three main ELV stakeholders—grid managers, vehicle operators, and charging network owners—need to collaborate to identify the optimal integrated charging system and work with policymakers to promote infrastructure deployment that supports the whole market.

1. THE SHENZHEN ELV MARKET IS HIGHLY FRAGMENTED WITH A LARGE NUMBER OF COMPANIES DEPLOYING ELVS THROUGH LEASING MODELS

Production of ELV vehicles is fragmented, with 45 different brands competing for market share. ELVs in Shenzhen are primarily light delivery vans and light enclosed box trucks (less than six meters in length and a gross vehicle weight rating of <4.5 tons)[22] used in final mile urban delivery (Exhibit 9). The top three ELV brands are Dongfeng Motor, Jiangsu Green Wheel, and Chengdu Dayun, which have a collective market share of 37% (Exhibit 10).

Leasing companies own and deploy 98% of ELVs in Shenzhen. The companies typically bundle provision of the vehicle, maintenance of the vehicle, provision of charging infrastructure, and, at times, even the driver of the vehicle.[23] This allows vehicle users to obtain the vehicle and associated services with only a monthly payment. There are four main reasons for the prominence of this leasing model:

1. **Significant upfront capital** is needed to acquire ELVs and provide the necessary charging infrastructure, which can be mobilized at lower cost by large, well-capitalized companies.

2. **A policy preference for commercial**, rather than personal, ownership of ELVs, given access to subsidies for commercially registered ELVs.

3. **Total cost of ownership is minimized** by leasing companies' abilities to tailor vehicle specifications, especially battery size and truck carrying capacity, to client use patterns.

4. **Maintaining and servicing of ELVs requires a unique skill set** that most carriers do not possess. Leasing companies specializing in ELVs have grown this expertise in house and make it available to clients.

The ownership of ELVs is significantly more consolidated than their production with the top three players—Shenzhen Xinwo Transport, Shenzhen Green Star Leasing, and Shenzhen DST—owning over 50% of all ELVs registered in Shenzhen (Exhibit 11).[24]

EXHIBIT 9

ELVs in Shenzhen by Type

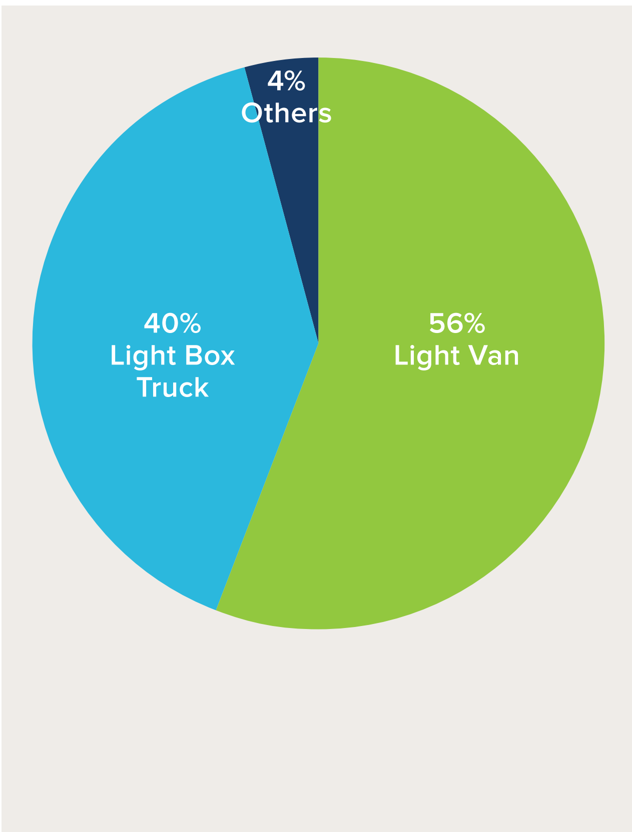
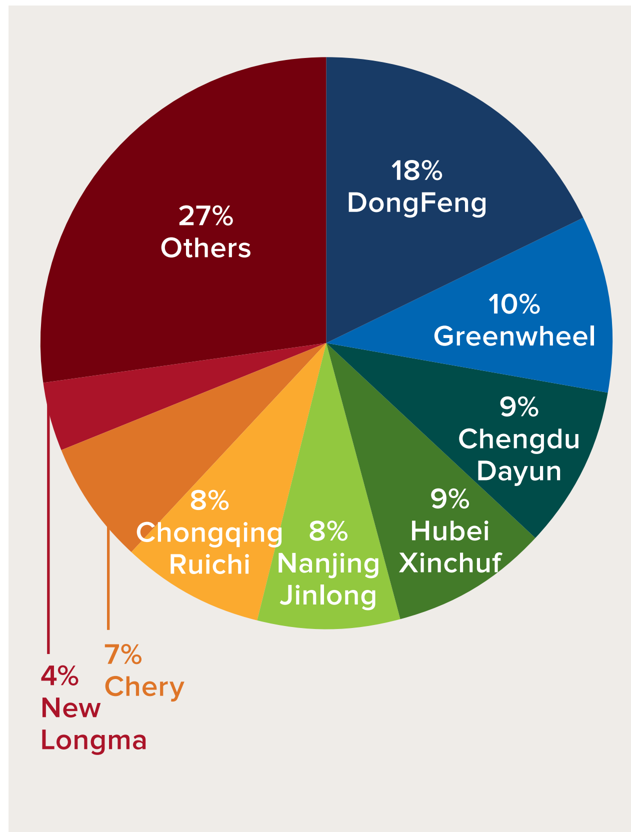


EXHIBIT 10

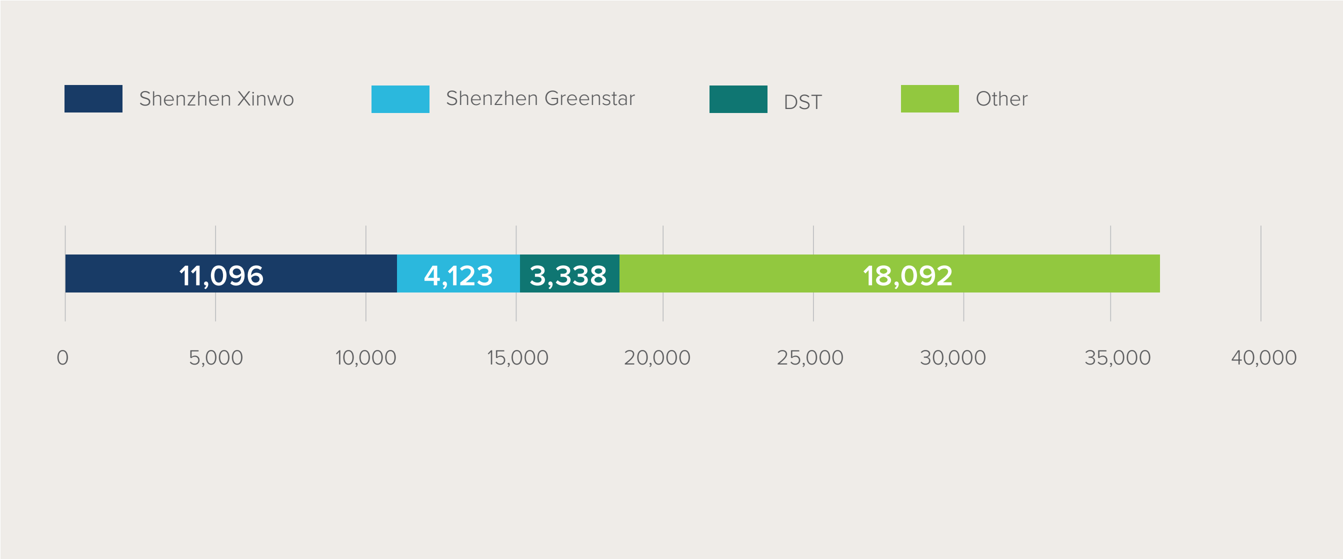
ELVs in Shenzhen by Original Equipment Manufacturer



Source: Shenzhen EV Application and Promotion Center 2017 New Energy Urban Delivery Trucks Application and Promotion Annual Report

EXHIBIT 11

ELV Registrations in Shenzhen by Owner



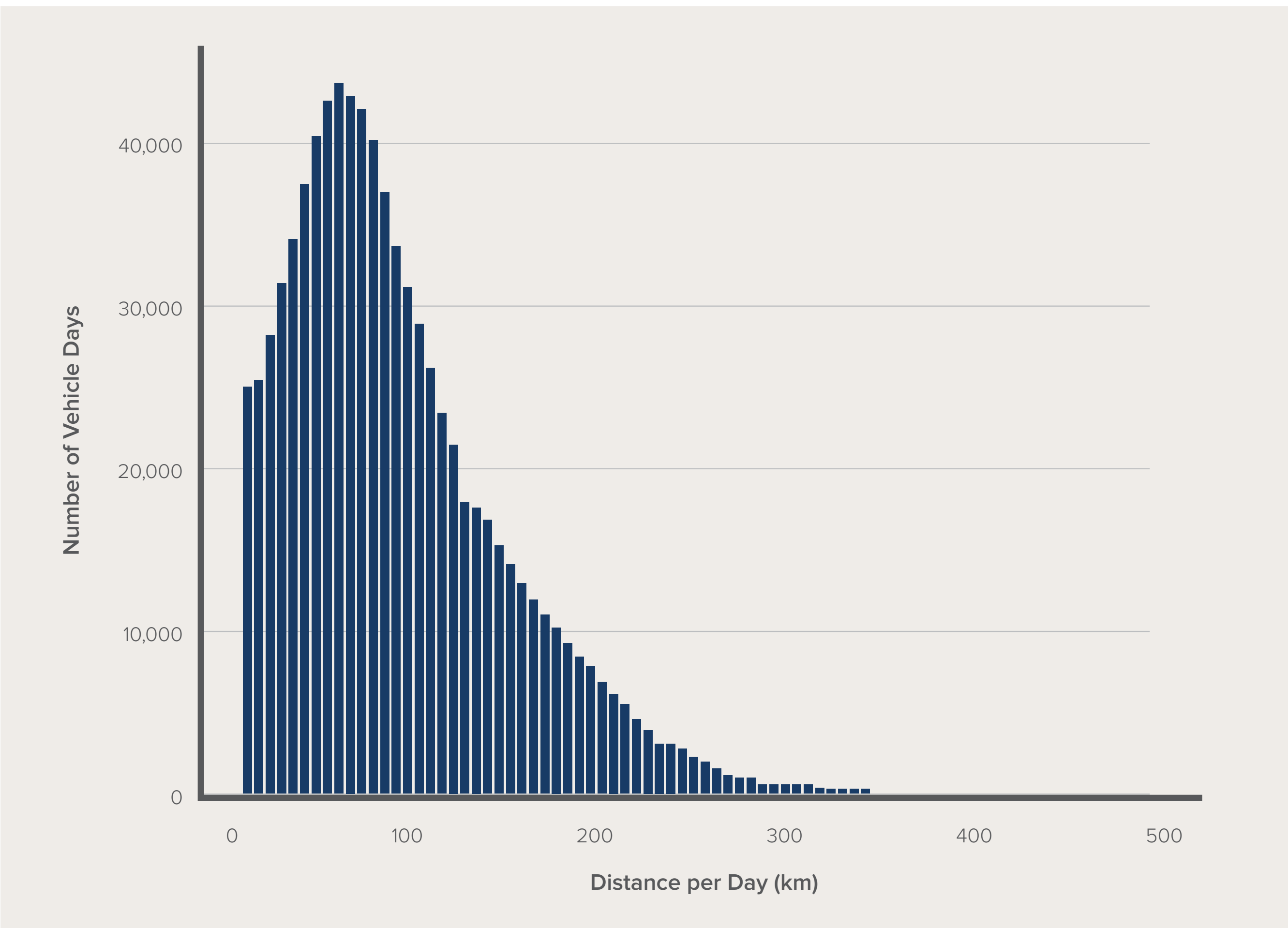
Source: Shenzhen EV Application and Promotion Center 2017 New Energy Urban Delivery Trucks Application and Promotion Annual Report

2: ELVS HAVE MODERATE SIZE BATTERIES THAT COMFORTABLY SUPPORT ONCE-PER-DAY CHARGING

For the vehicles in Shenzhen's ELV data set, battery pack capacities range from 38 to 100 kWh, with the majority of vehicles falling between 40 and 60 kWh. The preponderance of vehicles within the 40–60 kWh range suggests that most urban deliveries in Shenzhen can be accomplished with those moderately sized packs, but that a nontrivial portion of demand requires greater power and range. This conclusion is largely confirmed by the average daily driving distances of ELVs in Shenzhen. Of the approximately 800,000 vehicle-days in the data set, the median vehicle-day (defined as a day in which a vehicle drives more than 5 km) has 65 km driven, but with a wide distribution around that mean value (Exhibit 12).

EXHIBIT 12

Distribution of Distance per Vehicle-Day



Source: RMI Analysis

3: ELVS OPERATE IN UNDERSTANDABLE PATTERNS IN SPACE AND TIME BASED ON KEY ATTRIBUTES OF THEIR SERVICES

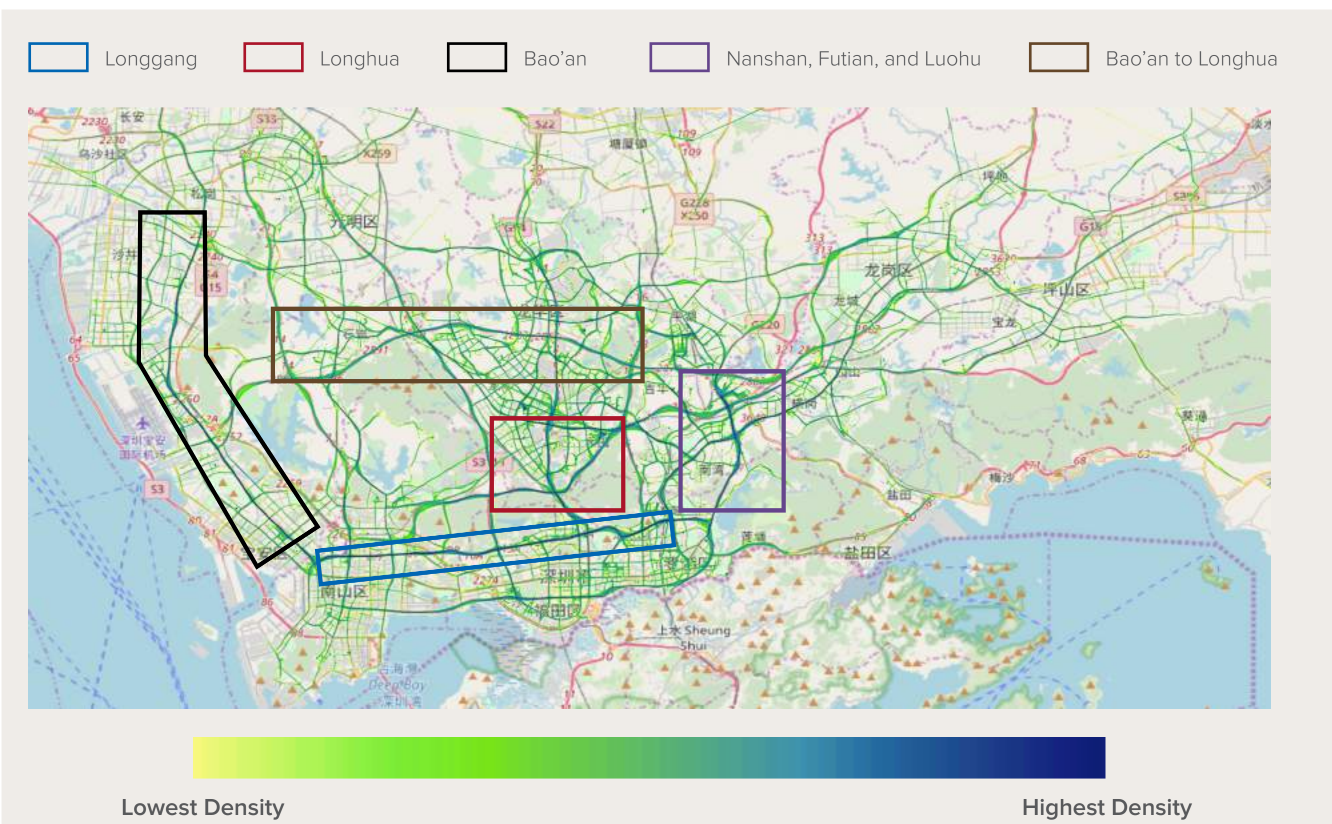
Routes Traveled

While battery pack capacity and daily driving distances are the main determinant in how often a truck must charge, where a truck drives is the main determinant in where it stops to charge. Cumulative travel and delivery patterns show that truck travel is concentrated on a limited number of relatively dense routes. Exhibit 13 highlights the primary routes that could be investigated for further charger deployment, including:

- Routes providing urban access from the logistics parks in Longgang (blue rectangle) and Longhua (red rectangle)
- The route providing urban access through Bao’an (black shape)
- The route providing mobility across Nanshan, Futian, and Luohu (purple rectangle)
- The route connecting Bao’an and Longhua (brown rectangle)

EXHIBIT 13

Routes Used by ELVs in Shenzhen



Source: RMI Analysis

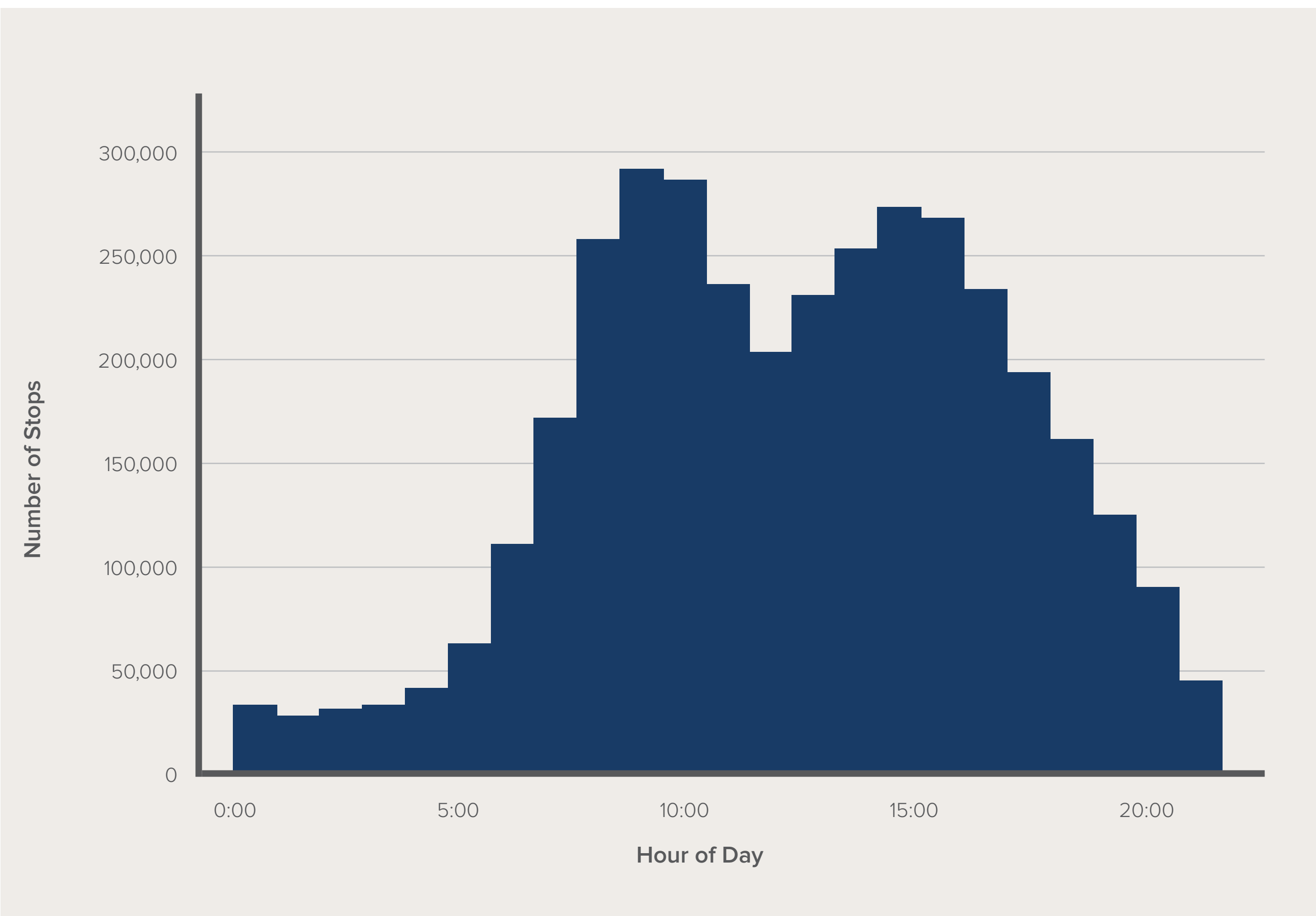
Operational Stops, Overnight Idling, and Charging

ELVs operating in Shenzhen routinely make stops to deliver and pick up goods. The distribution of those stops over time shows a clear pattern of daytime operation, with downtime in the early afternoon between noon and 2:00 p.m., likely for a lunch break, and the highest shares of delivery being done midmorning and the midafternoon (Exhibit 14).

Stops tend to be relatively short, with most stops lasting less than 30 minutes (Exhibit 15).[iii] This relatively short stop duration is consistent with e-commerce fulfillment and parcel delivery, which was identified as a major component of ELV use in Shenzhen.

EXHIBIT 14

Number of ELV Stops in Each Hour of the Day

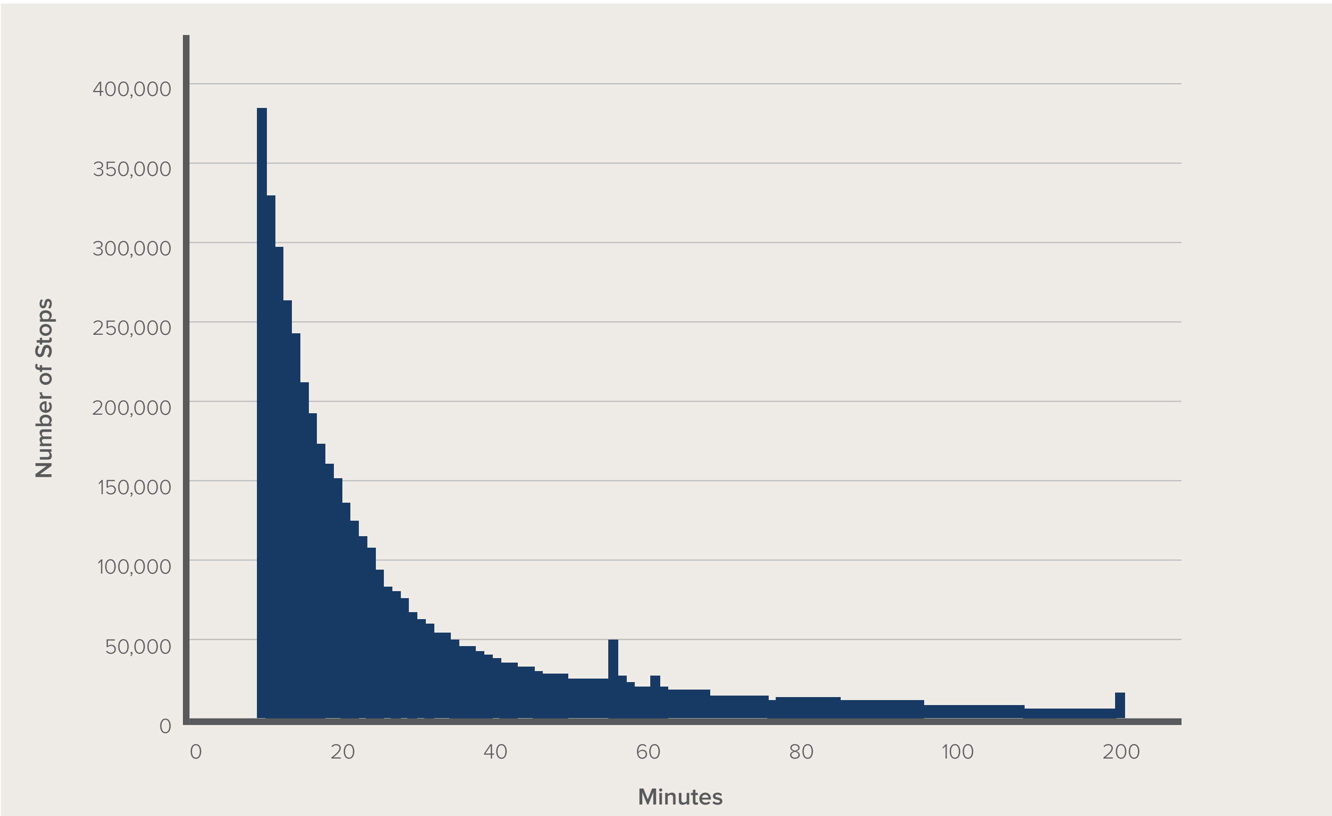


Source: RMI Analysis

[iii] Stops shorter than 15 minutes were excluded from this analysis as many were attributable to traffic congestion.

EXHIBIT 15

Number of ELV Stops in Shenzhen by Duration

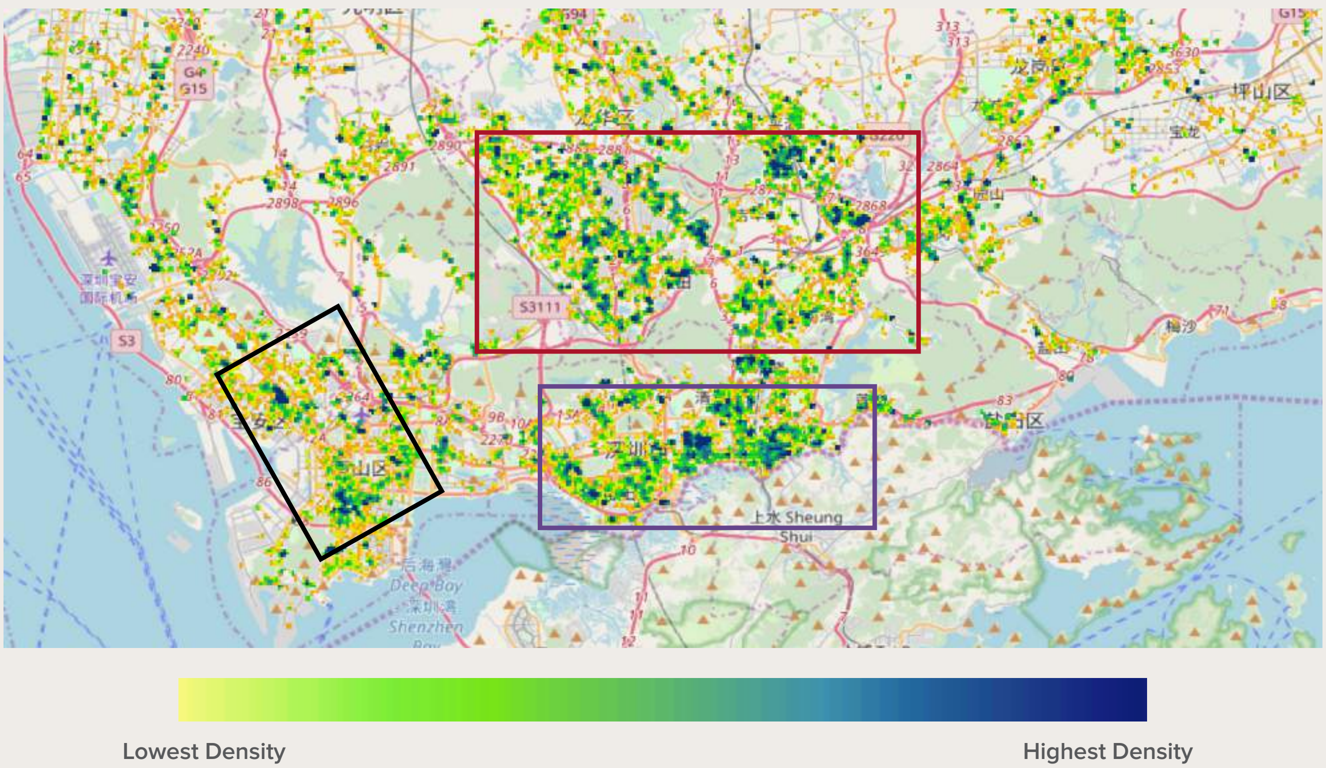


Source: RMI Analysis

Operation stops tend to occur in two types of key points in the ELVs' routes: 1) logistics parks and warehouses, where they pick up goods, and 2) high-density commercial areas, where they deliver goods (Exhibit 16). Understanding the density of stops is important to evaluating where demand for charging services exist. This is particularly relevant to the Shenzhen ELV market, given that trucks usually charge during daylight hours at fast chargers (discussed in further detail below).

EXHIBIT 16

Heatmap of Operational Stops in Shenzhen



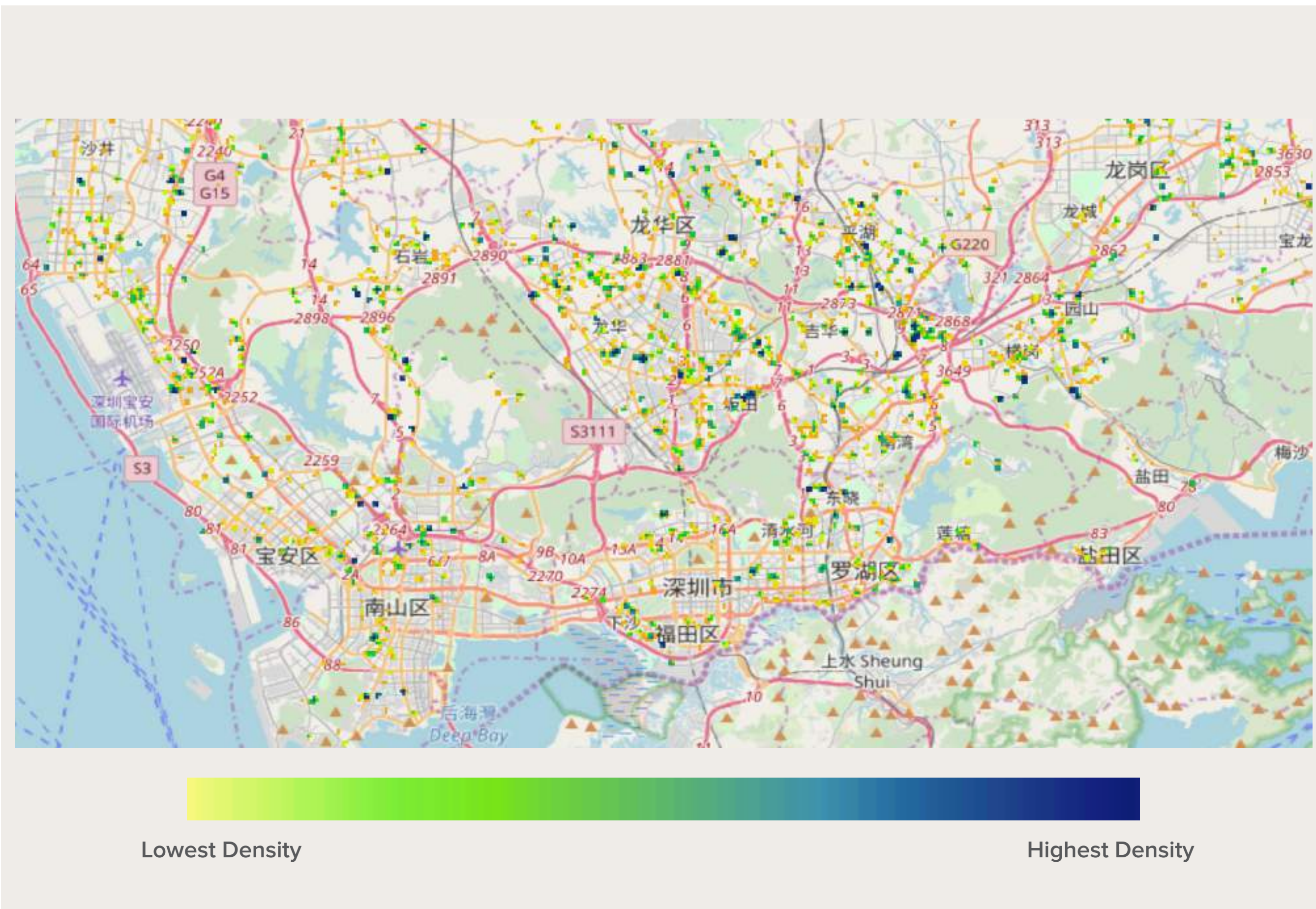
Note: The logistics parks and warehouses are concentrated in Longgang and Longhua districts (outlined in red) as well as in Bao'an and Nanshan (outlined in purple), whereas delivery points are primarily in the central zones of Futian and Luohu (outlined in blue).

Source: RMI Analysis

Where trucks spend the night is also a critical element of charging network design because it shows where slow-charging infrastructure may be deployed. The data indicates that ELV overnight stops primarily occur at logistics centers and in the outer suburbs, but there is relatively little activity in the city center (Exhibit 17). This is consistent with our interviews, which indicated that ELVs primarily park overnight at logistics centers and drivers' homes in the suburbs.

EXHIBIT 17

Heatmap of Overnight Stopping Locations of ELVs



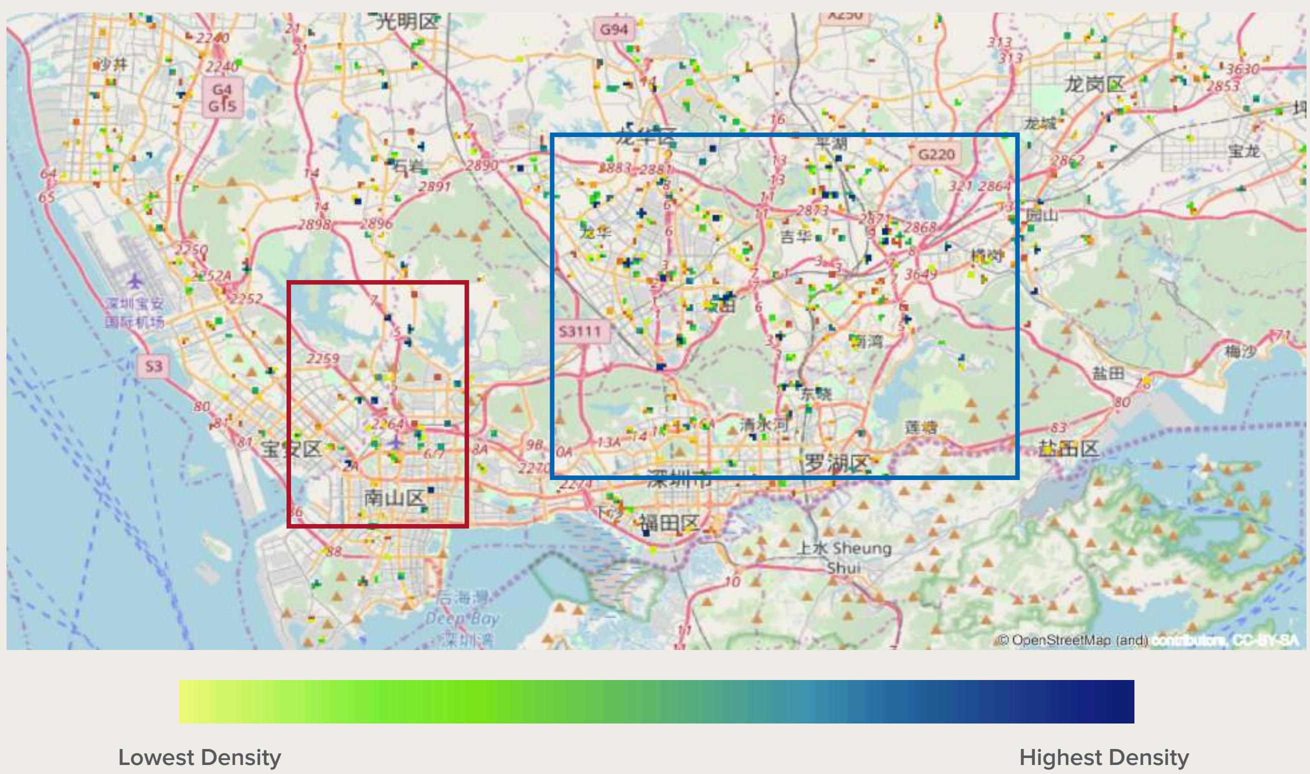
Source: RMI Analysis

4: AVAILABLE CHARGING LOCATIONS DO NOT ALIGN WELL WITH ELV CHARGING NEEDS

Seeing where vehicles actually charge compared with where they drive, spend the night, and make deliveries provides insight into areas where the charging network could be improved. Charging is mostly concentrated in the logistics parks of Longhua and Longgang (outlined in blue) as well as in southern Bao'an and Northwestern Nanshan (outlined in red). There is relatively little charging both in the northern suburbs, where operators park their trucks overnight, and in the city center, where most trucks make their deliveries (Exhibit 18).

EXHIBIT 18

Heatmap of ELV Charging Locations



Source: RMI Analysis

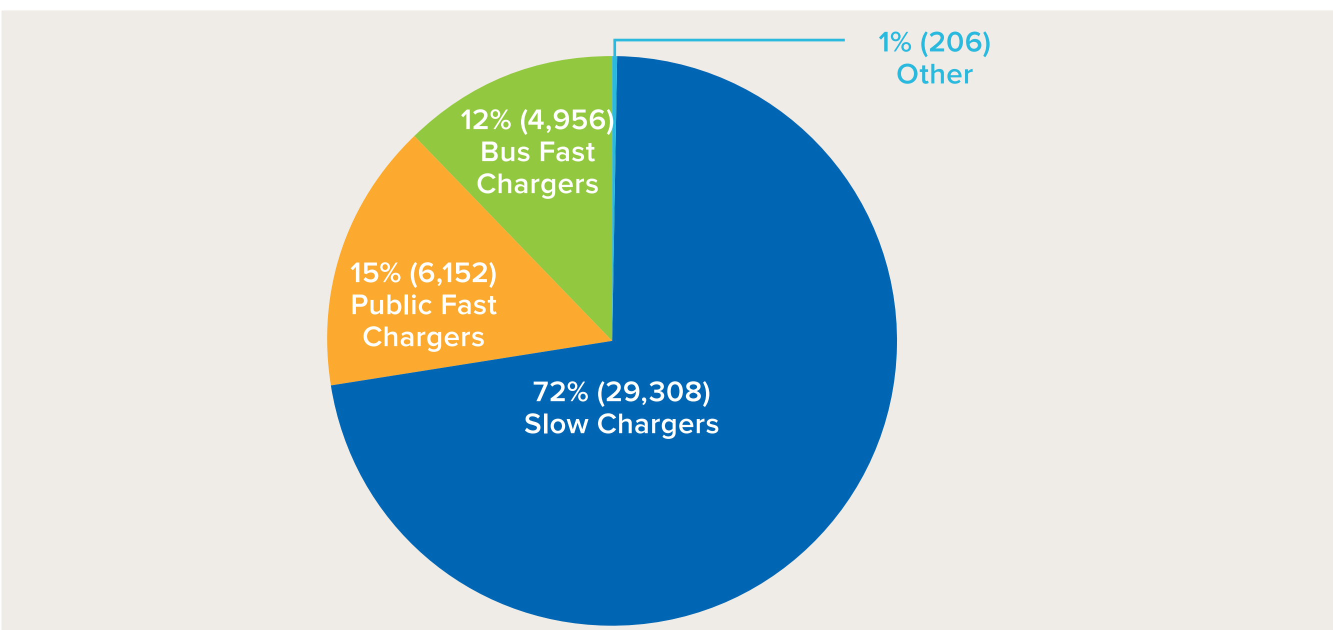
This geographic distribution of charging confirms several insights gathered from interviews. First, ELVs that are part of large fleets charge at their logistics centers, which are concentrated in the suburbs of Longgang and Longhua directly north of the urban areas of Futian and Luohu. Second, operators typically are unable to charge at their homes in the outer suburbs at night but rather use fast chargers in the inner suburbs or city center during the day. Third, trucks are unable to charge in the city center where they primarily operate. If they need to top up during the day, they must either drive to the suburbs to charge at large charging stations or queue at smaller, crowded stations in the city center.

5: THE CHARGING STATION MARKET, PARTICULARLY FOR FAST CHARGERS, IS GROWING RAPIDLY AND IS HIGHLY FRAGMENTED

In order to keep pace with the rapid growth in ELVs, Shenzhen is actively deploying an extensive network of charging stations. As of the end of 2017, 40,622 chargers had been installed citywide. Exhibit 19 shows the breakdown of those chargers; 75% are slow chargers and the remaining 25% are fast chargers split between public fast chargers and electric bus chargers.[25] Given that approximately 40,000 ELVs are currently registered in Shenzhen, a ratio of approximately 1:1 of chargers to ELVs would appear to be sufficient. However, that number may overstate the actual availability of charging stations to ELVs for two reasons. First, many of the slow chargers are not available for public use; they are privately owned by personal EV owners. Second, many public chargers are not functional.

EXHIBIT 19

Chargers in Shenzhen by Type



Source: Shenzhen EV Application and Promotion Center 2017 New Energy Urban Delivery Trucks Application and Promotion Annual Report

According to an investigation conducted by Shenzhen's three major charging operators, more than 54% of public chargers, primarily slow chargers, are damaged or otherwise unsuitable for use.[26] While a comprehensive study has not been conducted, there are two hypotheses for the potential causes of the high share of inoperable chargers. First, in the early days of charging station network deployment, there was no planning process to select sites for chargers. Operators were allowed to put chargers on any land they were able to secure rights to use and built chargers to essentially "save" spots without ever connecting them to the electricity supply. Second, the charging market in Shenzhen is highly fragmented with many small players that are poorly capitalized and have not been profitable. Many loss-making charging stations have fallen into disrepair because they are not worth maintaining or their owners have gone out of business. This high share of nonfunctional and captive slow chargers means that the actual number of chargers available for ELVs is far below the 1:1 ratio suggested by the total charger population. Although the exact ratio of ELVs to usable chargers is not known, the fact that many ELVs must queue at the most popular charging stations strongly suggests a shortage in supply and inefficiencies in its distribution.

A final notable feature of the charging market in Shenzhen is fragmentation. Due to the aggressive policy incentives, many startups have entered the market. Currently more than 40 charging station owners are operating in Shenzhen. This high fragmentation has led to disorderly market conditions. In response, the government has implemented policy, as discussed earlier, aimed at driving consolidation in the market.

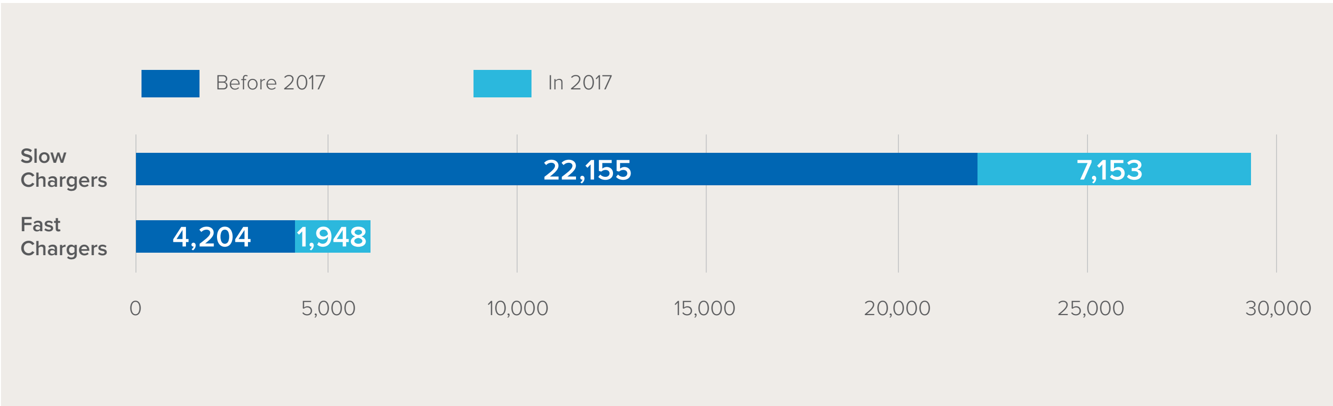
6: ELV OPERATORS HAVE A CLEAR PREFERENCE FOR FAST CHARGING

The ELV charging market has a clear preference for fast charging. On average, the daily use of public fast chargers is 120 kWh versus less than 1 kWh for slow chargers.[27] That utilization gap suggests that, while slow chargers are more numerous than fast chargers, fast chargers actually play a much larger role in the provision of charging services for EVs in Shenzhen. This is particularly true for ELVs, which use fast charging nearly exclusively. With the increase in the number of vehicles that prefer fast charging, such as taxis and ELVs, the deployment of fast chargers has accelerated. In 2017, 11,586 chargers were installed, which represented 29% of the total existing chargers. Of the 11,586 chargers, 27% were public fast chargers. Prior to 2017, 19% of chargers installed were public fast chargers (Exhibit 20).[28]

There are several reasons for the preference for fast charging. Slow charging requires seven to eight hours to charge an ELV from empty to full, while a fast charger only needs about two hours. Second is price parity; although the difference in charging speeds of slow and fast charging is significant, the average price of fast charging is only 0.2 RMB/kWh higher than slow charging due to the regulated prices that charging station operators may charge. Even that small advantage is eroded by parking costs because 80% of slow chargers available for ELV use are located within parking lots that charge parking fees whereas fast chargers are mostly established in special use areas with unlimited free parking, such as logistics parks.[29] Given that only the first two hours of parking for ELVs is free, the parking fees for the remaining four to five hours of parking required to slow

EXHIBIT 20

Chargers Installed in Shenzhen Through 2017



Source: Shenzhen EV Application and Promotion Center 2017 New Energy Urban Delivery Trucks Application and Promotion Annual Report

charge an ELV result in a greater total cost for slow charging than for fast charging. Third, since most slow chargers that are available for ELV use are located far from drivers' homes, charging at slow chargers during the night, the only viable option for a seven- to eight-hour charge time, is also not a favorable choice for users. A final reason for the preference for fast chargers is the widely used truck leasing models discussed above. Leasing companies provide bundled services to many clients and therefore must ensure that infrastructure is able to serve all of those clients. That leads to a preference for creating large charging stations with fast chargers in high-use areas, rather than putting in slow chargers at driver's homes, which would be essentially captive to that one driver. This preference for fast charging results in public slow chargers being unable to obtain the utilization necessary to be financially sustainable. As seen below, a fast charger with average utilization is able to produce a healthy internal rate of return (IRR) of 17%, which is greater than the cost of capital for most charging station owners. Slow chargers, on the other hand, produce an annual operating loss and therefore never recover their initial investment.

EXHIBIT 21

Chargers Installed in Shenzhen Through 2017

	Fast	Slow
Initial Cost (RMB)	175,000[30]	8,500
Initial Subsidy (RMB)	36,000[31]	2,100[32]
Adjusted Initial Cost (RMB)	139,000	6,400
Service fee (RMB per kWh)	0.8[33]	0.8
Power (kW)	60[34]	7
Utilization (hrs/y)	8.33%[35]	0.60%[36]
Annual Revenue (RMB)	35,025	294
Annual O&M (RMB)	5,000	2,000
Annual Operating Profit (RMB)	30,026	-1,706
IRR	17%	N/A

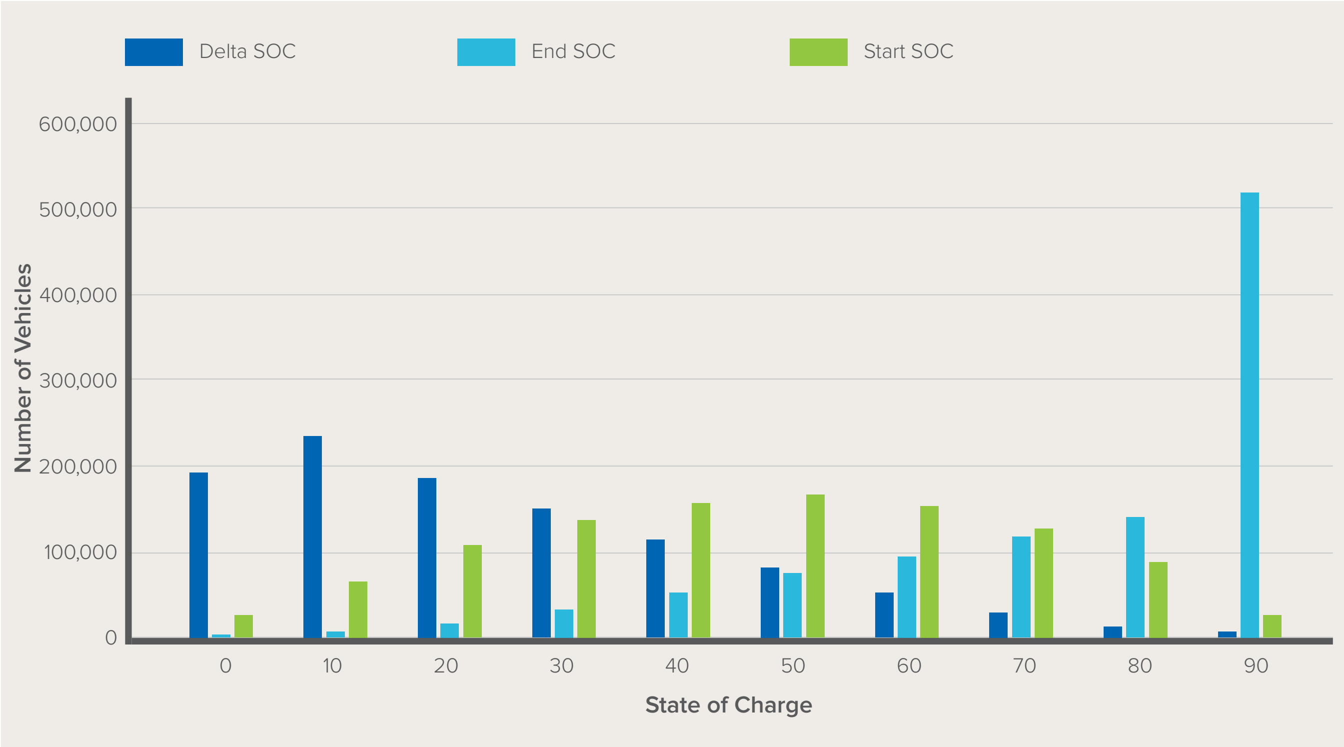
Source: Teld New Energy Co., Potevio New Energy Co., and Southern Heshun, Shenzhen e-Truck Charging Station Operational Status Survey and Investigation

The preference for fast charging expressed in interviews is confirmed by ELV charging data. As seen below, the majority of charging events typically begin with a starting SOC of around 50%, charge to over 90%, (Exhibit 22) and last less than 180 minutes (Exhibit 23);[iv] for charge times lasting less than three hours, which likely means fast charging, the median duration of charge sessions is approximately 80 minutes (Exhibit 24). However, there is a noticeable second peak in the distribution of around 500–600 minutes, which is likely overnight slow charging (Exhibit 25).

[iv] Charge times in which less than 5% of battery capacity was gained were removed from consideration as regenerative braking can be misinterpreted as very short duration charge events.

EXHIBIT 22

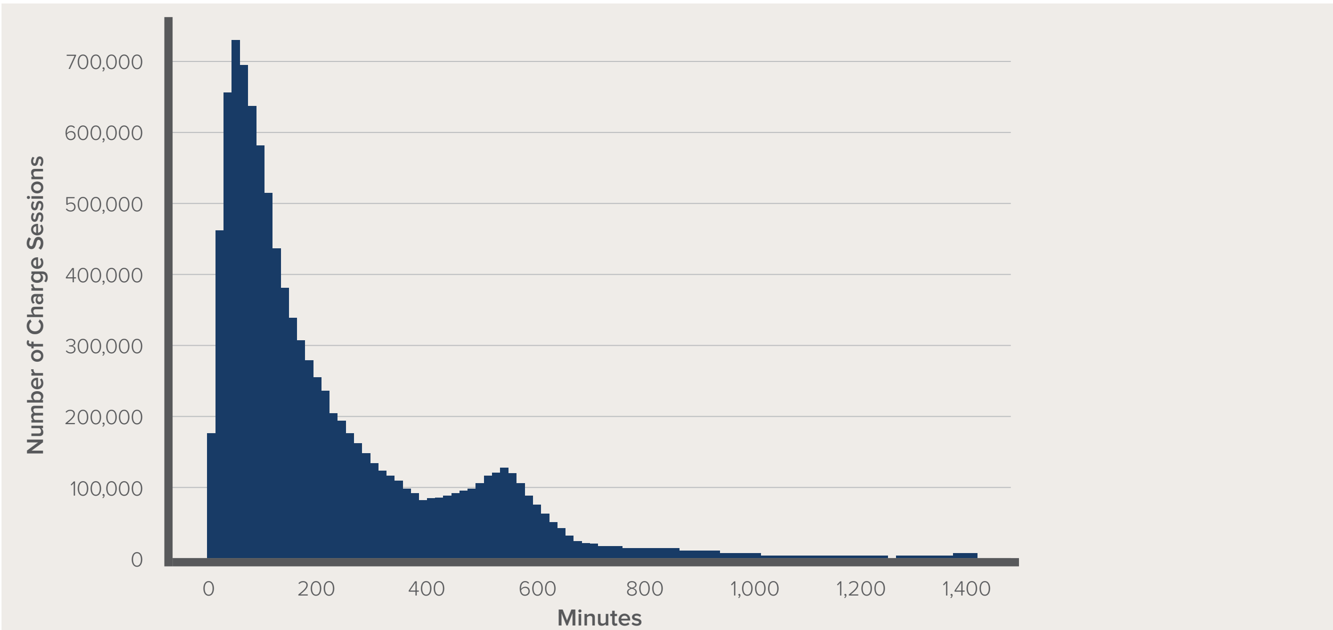
ELV States of Charge and Their Change During Charging



Source: RMI Analysis

EXHIBIT 23

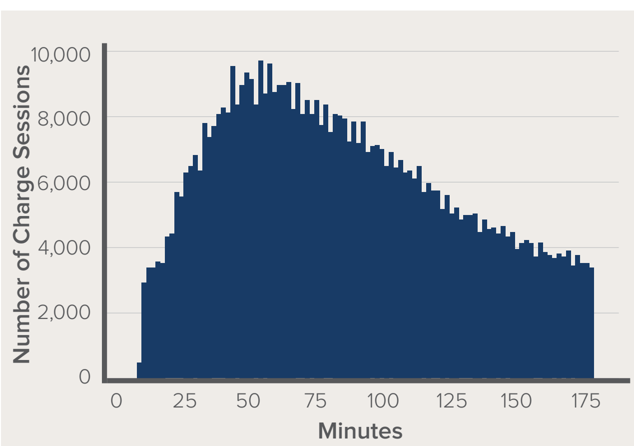
Duration of ELV Charge Sessions



Source: RMI Analysis

EXHIBIT 24

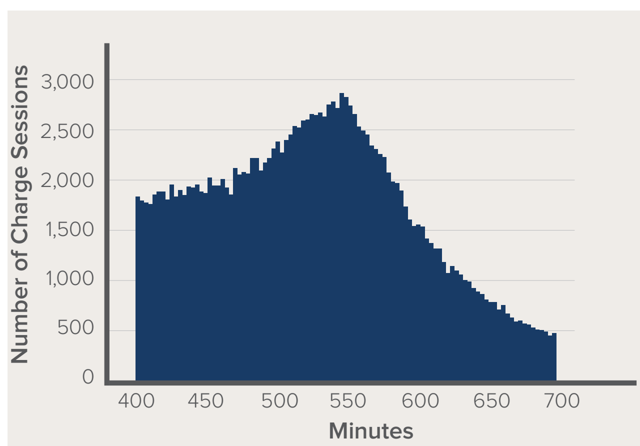
Duration of ELV Fast-Charging Sessions



Source: RMI Analysis

EXHIBIT 25

Duration of ELV Slow-Charging Sessions



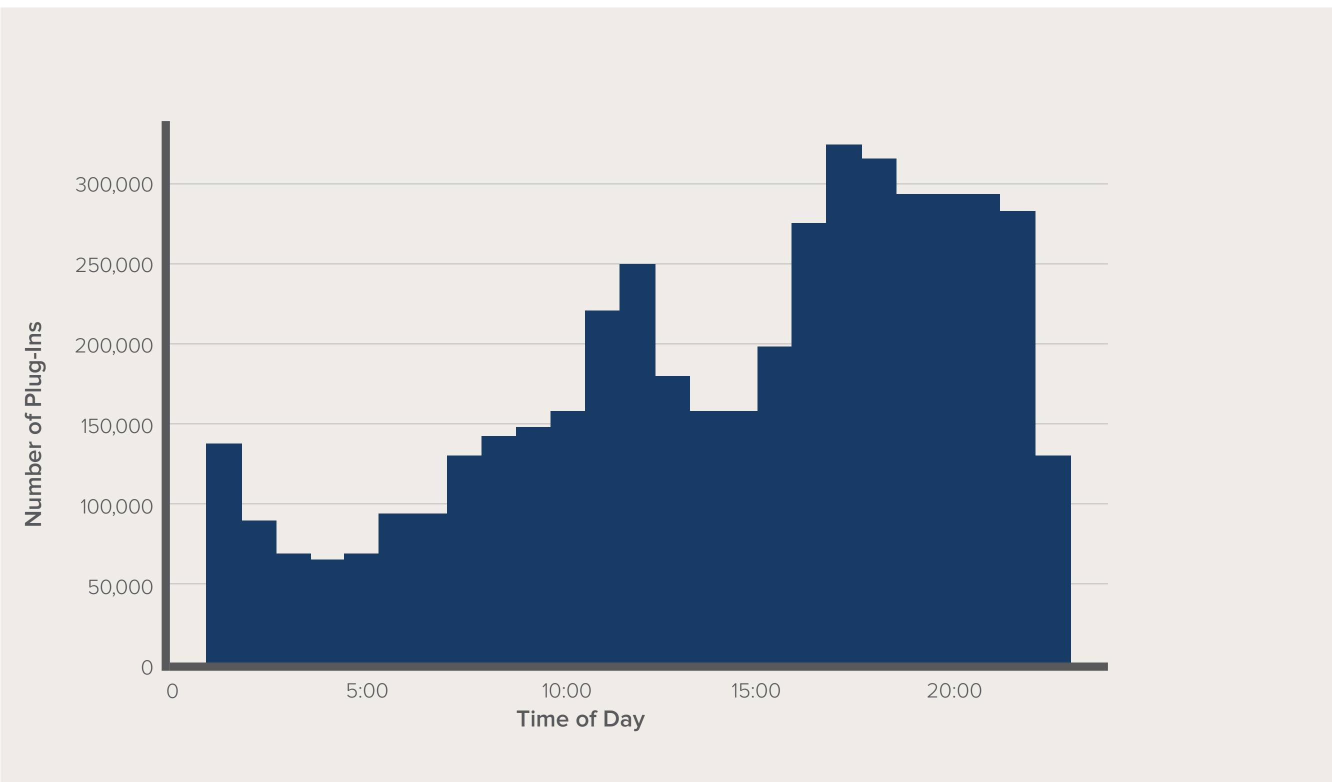
Source: RMI Analysis

7: ELV OPERATORS CHARGE THEIR VEHICLES STRATEGICALLY DURING BREAKS IN THEIR DAYS

In addition to the types of chargers being used, another key feature of the market for ELV charging in Shenzhen is when they are being used. As seen in Exhibit 26, charging sessions typically start in the morning before work, have a first peak around lunchtime, and then another peak after work in the evenings. The midday charge spike is approximately one to two hours before the midday delivery dip discussed above. This seems reasonable as charge sessions typically last around 90 minutes, and drivers would not be stopping to make deliveries while their trucks are charging. The evening peak suggests significant unrealized potential for slow charging at night. While the duration of charge sessions makes it clear most charge sessions, including those in the later afternoon and evening, use fast chargers, the timing suggests that these sessions take place after a driver's work day is complete. Reasons for using fast charging in those types of charging sessions and approaches for shifting them to slow charging are discussed further below.

EXHIBIT 26

Plug-In Times for ELV Charging by Hour



Source: RMI Analysis

4 PAIN POINTS AND MAJOR BARRIERS IN ELV CHARGING

PAIN POINTS AND MAJOR BARRIERS IN ELV CHARGING

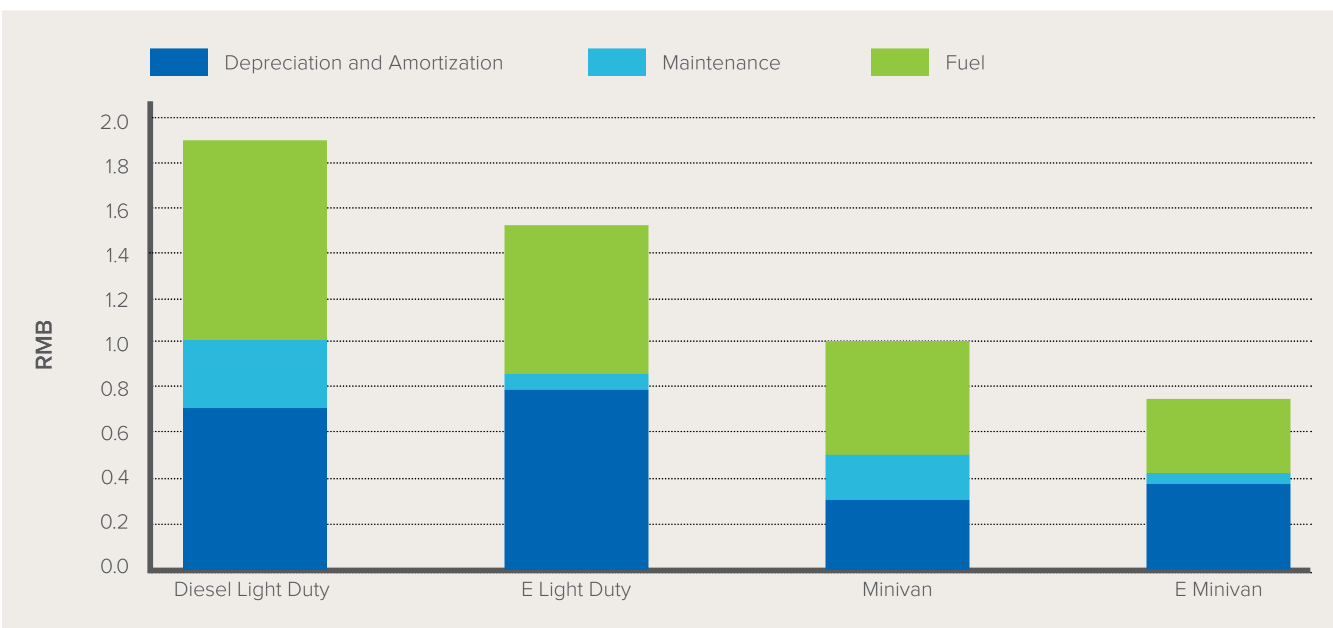
Although the market for ELVs in Shenzhen has developed very quickly, it is not yet fully mature. Pain points, especially those related to charging infrastructure, still exist for many stakeholders in the market. Addressing those pain points will both ensure the continued adoption and use of ELVs in Shenzhen and offer critical guidance for other cities that seek to achieve similar electrification outcomes without the same learning-by-doing that, as a global first mover, Shenzhen had to engage in. Those pain points from three major stakeholders—carriers/rental companies, charging stations operators, and grid operators—are discussed in the following sections.

CARRIERS AND RENTAL COMPANIES

The two main considerations when choosing between diesel trucks and ELVs, apart from specific occasions where cargo owners request ELVs for sustainability reasons, are delivery vehicle productivity and total cost of ownership. For ELVs, the cost tradeoff is favorable due to the subsidy program, which greatly reduces the upfront cost gap between ELVs and their ICE competitors, and the lower operation costs of ELVs. Together these two factors create total cost of ownership superiority for ELVs (Exhibit 27). However, which type of vehicle enjoys better productivity is less clear. On one hand, ELV productivity is supported by favorable terms of urban access. On the other hand, the time required to charge, which can be exacerbated by paint points discussed below, can push the productivity balance back in favor of ICE delivery vehicles.

EXHIBIT 27

Cost per Kilometer and Its Composition for Vans and Light-Duty Trucks[v]



Source: RMI Analysis

[v] Assumes 20,000 km per year and a 10-year operational life.

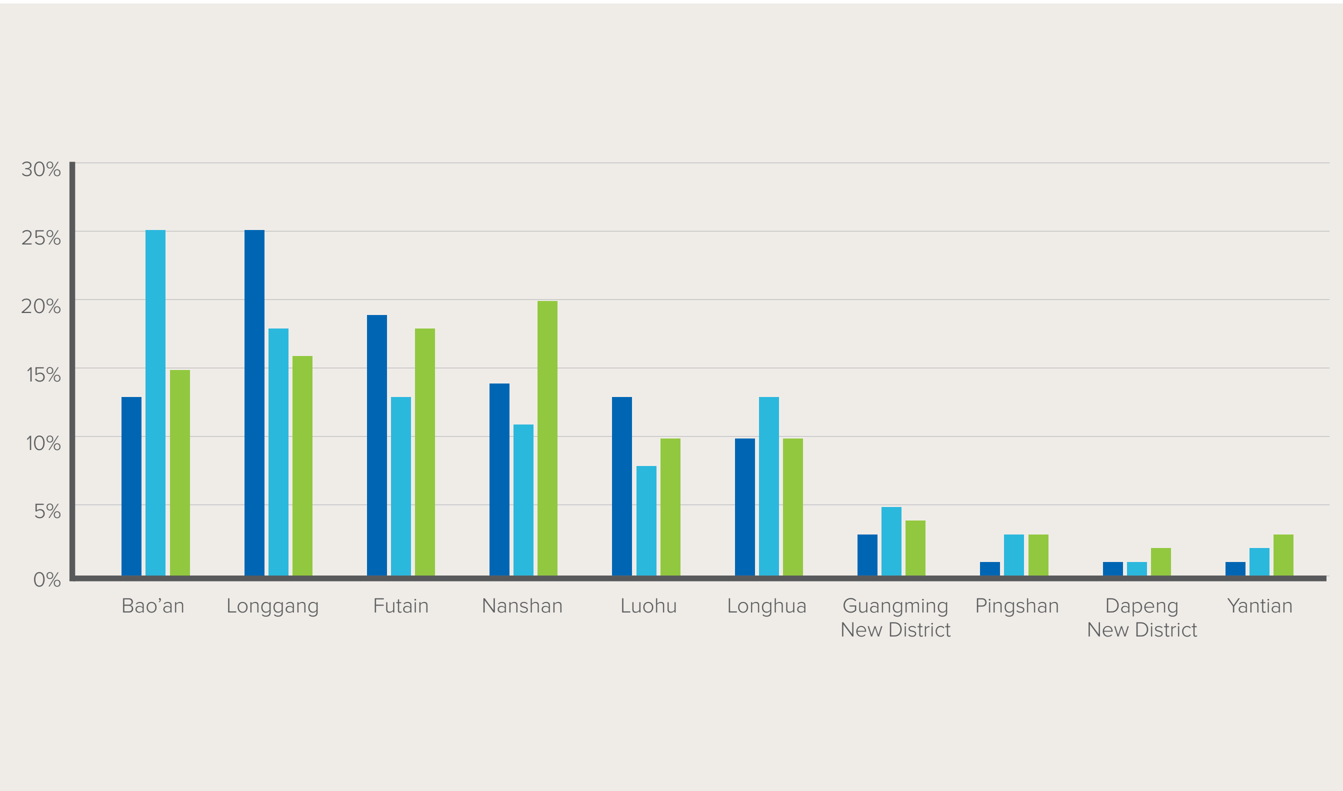
Insufficient Number and Uneven Regional Distribution of Charging Stations

The time taken to charge an ELV, especially under Shenzhen's current paradigm in which most charging occurs during the day, is a significant drag on productivity and a major competitive disadvantage of ELVs relative to ICE trucks. This inherent disadvantage of ELVs is exacerbated when charging stations are not readily available and drivers must travel long distance to get to a charger or queue at the charging station, as is sometimes the case in Shenzhen. This difficulty in obtaining charging services is caused by three main problems:

1. supply is not meeting demand both in location and number of chargers
2. ELVs are not allowed at some charging stations
3. parking spaces by chargers are occupied by non-EVs

EXHIBIT 28

Share of ELV Chargers, Population, and GDP for Shenzhen's Districts[37]



Source: Shenzhen Public Transportation Bureau, All New Energy Vehicles Chargers Spots in Shenzhen 2018.

Despite strong policy steps to support their deployment, the number of available chargers for ELVs is still insufficient and the location of available chargers does not align with the charging needs of ELVs.[38] Shenzhen's 2016–2020 development plan focuses on the establishment of several business districts with high demand for goods delivery, creating high truck traffic and, therefore, charge demand.[39] However, the provision of charging infrastructure has not been aligned with that development plan or the current geography of urban truck travel in Shenzhen. For example, Bao'an and Longhua, with their relatively large share of distribution centers, have the lowest shares of ELV charging infrastructure among the more central districts. Similarly, Luohu, with its high amount of deliveries, also has a relatively small share of ELV chargers. Instead, most ELV charging stations have been sited primarily in residential areas (Exhibit 28). This insufficiency of charging infrastructure in areas of high demand has created a supply shortage of charging services where it is needed. As a result, drivers often have to queue at charging stations in those areas, greatly reducing their daily delivery productivity.[vi]

Even in locations where sufficient charging infrastructure has been built, charging is limited because a significant number of charging stations are not open to use for ELVs. In a 2017 survey, 129 out of 607 (21%) of charging stations surveyed were completely private.[40] Furthermore, according to the interviews with ELV users and charger operators, many public charging stations are only open to electric sedans and forbid ELVs from charging due to their large size and relatively long charging times.

Another important reason for insufficient EV charging infrastructure availability is because many public chargers do not have exclusive rights to adjacent parking spaces. In Shenzhen, only 19% of charging stations have exclusive parking spots for EV charging, and only 11% of the charging stations are capable of monitoring parking spaces to ensure they are not being occupied by non-EVs.[41] As a result, up to 40% of parking spaces with EV chargers are generally occupied by nonelectric vehicles.[42] This is due to Shenzhen's lack of regulation governing the use of parking spots equipped with chargers in public lots. Rather, the city allows anyone to park in any space in public parking lots.[43]

Difficulty in Finding and Using Available Chargers

In Shenzhen, another charging-related pain point for ELV operators is service quality. That pain point encompasses two aspects: 1) there is no one-stop platform to find available chargers, and 2) the payment process is not user friendly. With regard to finding open chargers, drivers typically search either on an app operated by a charging station provider or via the provider's official WeChat channel. While nearly all charging companies have mobile apps and WeChat official accounts that provide charger searching services, they only carry information about their own charging stations. To reliably find the nearest charger, a driver would have to search each of the more than 40 provider's apps and WeChat accounts individually. Furthermore, many mobile apps and WeChat accounts do not provide customized search filters, such as charging connection type, vehicle model, fast or slow charging, way of payment, parking fees, etc., restricting their usefulness to a driver with specific charging needs. To further complicate the process, many mobile apps do not update charger information frequently enough or cannot provide any real-time information on charger availability. This results in ELV drivers going to unavailable charging facilities, wasting time and money as they are forced to queue for chargers that appeared available in online search tools.

[vi] Suburban districts of Shenzhen are large, so the district a charging station is in is only a partial indication of its suitability to operational patterns of ELVs.

Due to these challenges, many ELV drivers do not trust charging companies' apps. Instead, they choose charging facilities based on their own past experience. Some third-party apps do aggregate the data from each individual provider's app, but they are limited by the data available to them (they still suffer from the filtering issues and refresh issues mentioned above) and normally do not support payment.

Similar to locating a charger, the most common way to pay for charging is through the operator's mobile app or WeChat account, via a QR code on the charging station. However, since each operator has its own app and there are more than 40 charging station providers in Shenzhen, the burden of downloading and keeping so may apps and official accounts on a phone is quite high. And both mobile apps and WeChat require a stable internet connection around the charging area, which compounds the problem. Many underground parking spaces do not have a stable internet signal, so ELV drivers often have difficulties connecting to the internet for payment. Another common way of payment is with a prepaid card, but the difficulties of finding shops that sell those cards and the inability to check charging status remotely (a functionality offered in most apps) have limited user adoption.

Finally, software flaws, both on charging stations and on providers' apps, may create delays and financial risks to ELV drivers. Frequent system crashes, both during charging and during payment, either cause charge sessions to end prematurely or prevent drivers from paying for charging services once the session is done. Furthermore, many charging apps do not have robust communication security protocols, potentially allowing drivers' financial information to be stolen as they pay for charging services.

CHARGING STATION OPERATORS

Private owners of charging stations seek to earn a sufficient return on investment (ROI). Given that prices are regulated, meaning that the revenue per kilowatt-hour sold is fixed, charging station operators can generate an increased ROI by managing costs and/or increasing utilization. At current average utilization, fast chargers are able to make adequate returns, but slow chargers are not. However, fast-charging stations unable to generate sufficient utilization are financially unsustainable. Reducing costs, although possible, is often quite challenging for station operators. Below we discuss several contributing causes of unsustainable ROIs for charging station operators.

Low Utilization Rate

Because much of the revenue for public charging stations is regulated, the key driver of profit for those stations is utilization. Being able to capture sufficient business to earn an adequate rate of return is a crucial condition for continued operation. Since charging services are largely commoditized and drivers are typically indifferent to the various charging station operators, utilization of chargers is highly dependent on location. Chargers that are convenient for drivers gain high utilization and a healthy ROI, while chargers with less desirable locations earn lower, or even negative, returns.

This situation is a pain point for operators because they have limited flexibility in where they can install their stations. In order to establish a charging station, operators must first obtain approval that the grid can handle the new load. For large stations, gaining those approvals typically involves substantial improvements to the distribution grid. The stations that gain the highest utilization are typically in the areas where delivery trucks drive and operate. However, that is also where grid upgrades are the most difficult and costly. As a result, grid operators typically seek to steer charging stations toward areas in the suburbs where excess capacity exists or can be added easily. However, charging stations in those areas typically have poorer utilization rates. This fundamental conflict between the interests of the grid and the interests of charging station operators, combined with the grid's effective veto power on charging station installation, is a major pain point for charging station operators.

High Costs

Two elements comprise the cost structure of chargers in Shenzhen. Initial installation costs, including land cost and the cost of buying and installing the equipment, and ongoing operational costs, primarily maintenance.

Capex and land costs: Capex costs include the cost of purchasing both the charger and the cabling to connect it, the labor costs to install it, and time and effort spent getting approvals from the grid. For fast chargers these costs range between 150,000–200,000 RMB per fast charger, and 7,000–10,000 RMB per slow charger.[44] In addition to the direct costs of charger installation, station operators must also obtain use rights to the land where chargers are placed. Those rights are typically obtained either through a leasing or profit-sharing arrangement with property owners. If leased, the cost is typically 800 RMB per month per charger; if a profit-sharing model is used, land owners usually receive 20% of the charging fee collected by station operators.

Operation and maintenance cost: While chargers incur operational costs in the form of the electricity that they sell, those costs are not a major driver in station profitability. That is because those prices are regulated, are the same for all station operators, and are 100% passed through to customers. Therefore, the major operational cost item for station operators is maintenance.

Maintenance costs typically come from the repair and replacement of frequently used components such as power modules, electronic displays, and payment systems that all fail periodically. Among these components, power modules are the most vulnerable and the most expensive to replace. In normal operating conditions, they have a short average lifetime (about two years) and their field life is often much shorter as drivers do not always use them correctly. Furthermore, when a charging station does break, its repair is costly not only because the components themselves are costly but also because troubleshooting and fixing the problem require significant technical capability. While online monitoring tools allow station operators to know when a station has broken, they do not identify what elements of the charger have failed. That requires that all problems be diagnosed on-site by qualified field technicians. Only after that can needed parts be picked up and installed. The inefficiency of that system is a major driver of maintenance cost for station operators.

GRID

The rapid development of ELVs in Shenzhen created new opportunities for the local power supply company, China Southern Power Grid, to sell electricity but also created serious challenges to its distribution system. Those challenges come in two forms: 1) increases in peak demand that can overload elements of the distribution grid, and 2) the introduction of harmonic distortions into the grid, which can reduce the efficiency of power distribution or even destroy distribution grid equipment.

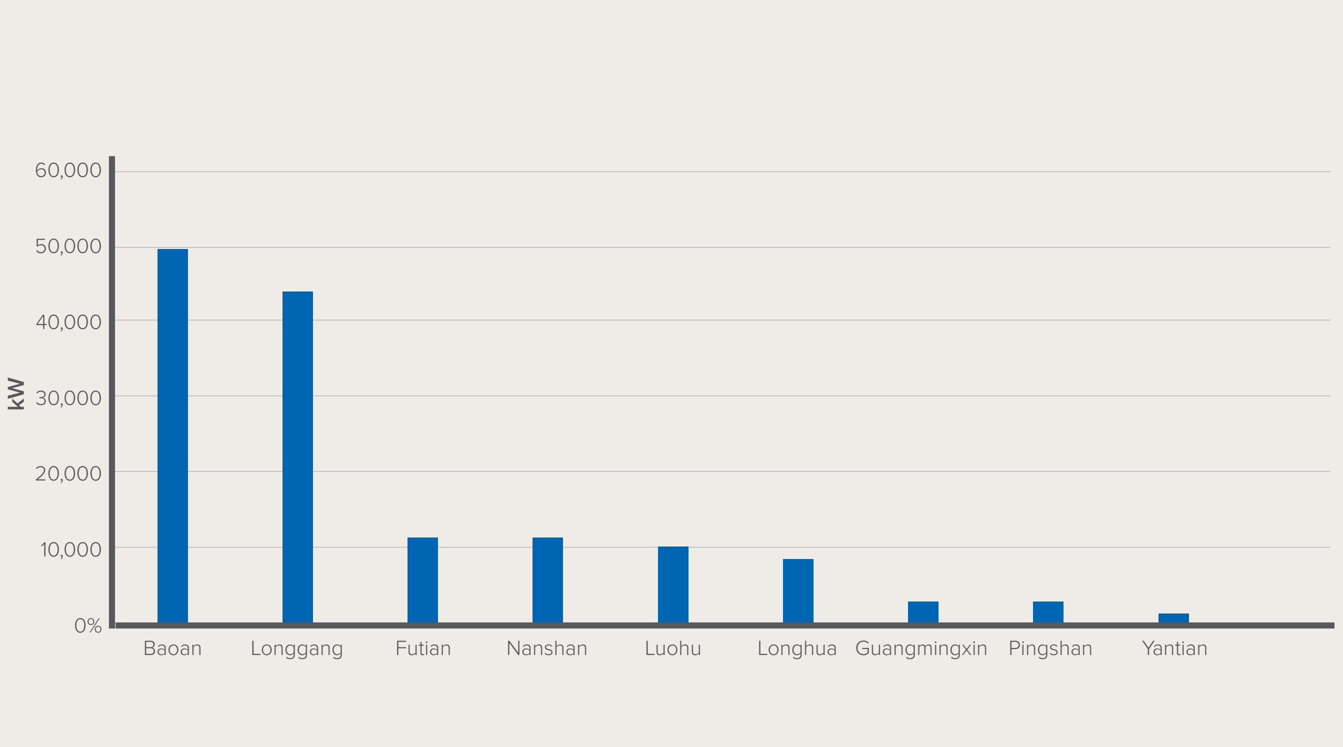
Increases in Peak Demand on Points in the Distribution Network

Electricity distribution grids are a collection of cables, transformers, switching equipment, meters, and other components. The distribution grid transfers power from high voltage transmission grids, which are directly connected to power plants, to electricity off-takers in a form in which they can use it. The equipment on the distribution grid is typically sized to support maximum expected load plus a safety margin. Any additional loads that raise those peaks require investment in new infrastructure or infrastructure upgrades.

ELV charging can raise peak power requirements significantly, especially in Shenzhen where several factors have combined to create significant new demand at peak electricity demand times. First, Shenzhen has emphasized the construction of large charging stations with many chargers to aggregate demand, which creates significant loads

EXHIBIT 29

Shenzhen Potential Grid Load Increase by ELV Charging[45]



Source: Shenzhen EV Application and Promotion Center 2017 New Energy Urban Delivery Trucks Application and Promotion Annual Report

on concentrated areas of the grid. Second, ELV users have shown a preference for fast charging, which draws large amounts of power in short periods of time. Third, ELV users have shown a preference for daytime charging, which is typically when other sources of electricity demand are high. Fourth, drivers have shown a preference to charge in a few relatively central areas of the city (Exhibit 29), where significant other loads exist and the ability to provide new upgraded distribution infrastructure is constrained. This combination of factors creates a perfect storm to overload the distribution grid. Fast charging creates demand for large amounts of power over short time periods, daytime charging causes that demand to coincide with other large grid loads, aggregation concentrates all of those loads at specific areas of the grid, and a preference for charging in the densely developed areas makes grid upgrades to accommodate that incremental peak load very expensive.

Harmonic Distortions on Distribution Grid Lines

Electricity on the distribution grid is transmitted with alternating current. The rate at which that current changes is known as the fundamental frequency of the grid. Equipment with power electronics, such as a DC fast charger, are known as nonlinear loads and can introduce frequencies into the distribution grid that are different from the fundamental frequency. These different frequencies can combine harmonically with the fundamental frequency in ways that can cause current distortions on the distribution grid. These distortions can overheat cables, transformers, and other grid components, causing them to fail, either catastrophically in a fire, or more gradually as components such as insulation or oil deteriorate more quickly, requiring early replacement. Harmonic distortions can also damage other equipment connected to the grid that is designed to use power transmitted at the fundamental frequency.

Again, Shenzhen's model of aggregated fast charging also creates potential concerns for harmonic distortions. Research shows that multiple DC fast chargers on the same distribution line can create harmonics that amplify each other rather than cancel each other out. In those cases, it can be the harmonic tolerances of grid elements, not the capacity of the transformer, that limit the ability of the grid to accommodate EV charging.[46] To avoid harmonic pollution damaging grid components or equipment connected to the grid, grid operators must invest in equipment that can filter out that harmonic pollution, adding to overall grid operator cost, or tighten standards on harmonic distortions created by chargers, potentially adding to charging station operator costs.

5 PATH FORWARD

PATH FORWARD

In order to resolve ELVs' charging-related pain points, charging station operators, China Southern Power Grid, and the Shenzhen government must cooperate to reform key issues in pricing policy and infrastructure development in order to incentivize the construction of an efficient, low-cost charging network. We suggest several potential measures here.

INTEGRATING ELV USAGE DATA INTO CHARGING STATION NETWORK PLANNING

In the current status quo, grid operators have a very strong role in determining the location of charging stations, both through their power to issue permits and their role in upgrading infrastructure to support charger load. This leads to site selections that primarily minimize grid costs, but often do so by creating greater costs to drivers and charging station operators. Those costs include poor charger utilization at less heavily used stations and queuing of ELVs at heavily used stations, a major pain point for both ELV and charging station operators. This dynamic is a key driver of uneven distribution of ELV charging stations discussed in the pain points section above. To date, Shenzhen has tackled the problem of ensuring the availability and convenience of charging stations through two main pathways. The first is extremely rapid network growth driven by subsidies and deployment targets, addressing the overall shortage of charging infrastructure. The second has been more granular charging station deployment targets on the district level, which helps network distribution to a certain extent.

A third pathway, integrated charging network planning, may enable Shenzhen to further tackle inefficiencies with the geographical distribution of its charging stations. To create such an integrated plan requires identifying sites that minimize total cost. To date, estimating what sites minimize costs to ELV operators, and therefore maximize charging station utilization, has been difficult. However, with the ELV telematics data set discussed in this paper, it is possible to estimate where those sites may be. Combining that ELV data with data from the distribution grid such as substation and cable location, load shape at network nodes over the course of the day, consumer electricity price, and existing capacity at those nodes, could enable identification of sites that simultaneously reduce costs to ELVs and charging station operators without excessively increasing costs to the grid.

Implementing such a solution would require collaboration across the ELV ecosystem in several forms. The first is in data sharing. As discussed above, ELVs already share operational data with a central data collecting platform, which is the source for the data discussed in this paper. In the near future, all chargers in Shenzhen will contribute data to a similar platform. Integrating the data contained in those platforms with data sets currently owned by Southern Grid would create the needed data to optimize charging station planning. Doing so would require collaboration with Southern Grid and the formation of an appropriate working group that guarantees the confidentiality and privacy of all data.

In addition to the practicalities of collaboration, another issue that would need to be addressed with an integrated plan is value distribution. Deploying charging infrastructure in places that increase grid costs but reduce ELV operator costs by a greater amount creates a net gain for society. However, it also creates a loss to the grid. Currently, with highly regulated pricing structures for ELV charging, there is no way for any of the gains accruing to truck users to flow to the grid. To overcome that value distribution problem, some price flexibility could be offered to allow the grid to capture a share of the created value to cover the costs it incurs. Alternatively, policymakers could decide to require the grid to accommodate charging infrastructure at high value sites with the cost of grid upgrades being recovered through rate basing.

PRICING FOR SPATIAL DEMAND MANAGEMENT

The fundamental source of the pain point of uneven charging station distribution is a misalignment of the location of demand for charging services with the location of the supply. Integrated network planning, discussed above, is a potential way to bring supply in line with demand. However, another viable approach that can be deployed simultaneously is to use price signals to bring demand in line with supply. To date, time-of-use (TOU) rates for electricity are the primary price signal used to manage overall electricity demand, including ELV charging. However, TOU rates, which do appear to influence driver behavior, only seek to influence the distribution of electricity demand over time—not over location. Extending the use of price signals to influence the spatial distribution of demand could lead to the creation of a lower cost system for charging. Specifically, areas where land and grid capacity can be provided cheaply, for example in less central areas of the city, could offer lower rates for charging whereas areas in the urban core could charge higher rates. Higher rates charged in the urban core could potentially come in the form of a feebate, which would then be passed on to users charging at less congested points on the grid or could be passed on directly to the grid to recoup expenses associated with grid upgrades necessitated by the increased load created by ELVs.

These types of approaches could also be calibrated to produce other benefits, such as congestion management. One of the policy approaches that has been deployed in Shenzhen to support ELV use has been to substantially increase road access rights for ELVs compared with ICE logistics vehicles. This approach makes sense because one of the major goals of the access restrictions was improved air quality; ELVs, which have zero tailpipe emissions, have no negative effects on air quality and therefore should not be covered by the ban. However, ELVs do contribute to Shenzhen's traffic congestion, the mitigation of which is another goal of the truck ban. As the ELV population continues to grow, its impact on congestion will worsen. Based on ELV charging times discussed above, drivers do attempt to charge during times of low productivity, such as rush hour. That could be supported with lower electricity prices at peak travel times along highly congested corridors and increased deployment of charging stations along those corridors. However, pricing for demand management would require an EV-specific tariff, which does not currently exist in Shenzhen. Implementing such a tariff is possible and has been done in other places but is not as simple as just formulating the pricing policy. In order for EVs to get different rates than other uses of electricity, charging stations would need to be metered independently. To do so, all EV chargers that currently share a meter with noncharging

uses would need to be outfitted with individual revenue-grade metering equipment—a potentially significant investment.

Because electricity rates are regulated and neither the grid nor charging station operators have any ability to set rates, enabling these types of pricing mechanisms would primarily fall on regulators and policymakers. Industry, including the grid, charging station operators, and vehicle operators, could support policymakers through consultation and analysis of the price points needed to shape demand effectively. Such a policy could initially be introduced as a pilot at a limited number of charging stations where results could be evaluated and policies could be refined.

COLOCATION OF DRIVER SERVICES FOR DEMAND MANAGEMENT

As discussed above in the context of congestion, drivers show patterns of charging their ELVs at times of low productivity, especially mealtimes when their trucks are idle. Drivers' preferences to charge while eating also creates a potential demand management opportunity that could shape the geography of charging demand, reducing the pain point of high grid upgrade costs without adversely affecting trucking productivity.

This strategy would seek to create large ELV charging stations that are colocated with restaurants and shops at strategic nodes on the distribution grid where grid upgrades could be provided cheaply. The convenience these types of facilities would create for drivers could enhance charging station utilization without the need for pricing mechanisms to attract customers. Furthermore, because they tend to have quite high profit margins, shops and restaurants owned by charging stations could enhance overall profit of the station. Because those types of retail establishments tend to be major profit drivers, charging station operators could afford to deploy sufficient chargers to avoid any queuing. This avoidance of queuing would, in turn, directly support truck productivity.

This strategy would primarily be executed by charging station operators, who would build both the charging stations themselves and likely also the ancillary services. Some collaboration with the grid would be required to identify high potential areas in the distribution grid and to deploy the needed infrastructure. However, this collaboration would likely be welcomed as it would reduce costs to the grid compared with the alternative of building more chargers in dense urban areas. Furthermore, the construction of a small number of very large charging stations likely has a lower unit cost for grid upgrades than a more dispersed deployment, again supporting lower grid costs.

ENABLING SLOW CHARGING AT NIGHT IN THE SUBURBS

A final strategy to address the pain points of uneven deployment of charging station infrastructure while simultaneously enhancing truck productivity and reducing grid upgrade costs would be to enable nighttime slow charging of ELVs. As discussed earlier, many ELVs spend the night in suburbs to the north of Shenzhen but very few actually charge there and very few charge overnight. A strategy to enable overnight charging in those suburbs would shape demand, both over time and location, in a way that is beneficial to the grid, incurs less cost in land use, and maximizes truck productivity.

While TOU rates do favor nighttime charging, several other factors do not. First, there is no strong price signal supporting demand shift into the suburbs; prices are comparable regardless of geography. Second, because charging stations' prices are highly regulated, the price paid by a truck operator for fast and slow charging is approximately equivalent. Third, charging station operators are reluctant to deploy public slow-charging stations because they obtain very poor rates of return due to low utilization; this problem is even more severe in suburban areas where the cost of maintaining a highly dispersed network is greater than in areas of higher density. Fourth, privately owned charging stations are not commonly used because drivers oftentimes do not own a parking spot, meaning they frequently will have other cars blocking their chargers. Finally, drivers are unwilling to invest in installing a private charging station both because they are cost sensitive and because driving urban delivery trucks is often not a long-term type of employment, curtailing the period for cost recovery, which is often quite long due to near price parity between public fast charging and private slow charging.

A strategy to incentivize nighttime slow charging would require that a charger be deployed within easy walking distance to a driver's home, in a parking space to which the driver has reliable access, and would be greatly supported by significantly lower unit charging costs than at fast-charging stations. As discussed above, that would require both an EV tariff for home charging and metering equipment for each charger. With regard to pricing, because slow charging greatly reduces the cost for needed grid upgrades, prices that transfer value from users of fast charging to users of slow charging are reasonable but are not currently possible in Shenzhen's electricity pricing regime.

PLANNING A COMBINED PARKING AND CHARGING SYSTEM

As discussed above, two elements of parking policy in Shenzhen cause pain points to ELV charging: 1) Shenzhen has no policy that restricts an ICE vehicle's ability to use a parking space equipped with an EV charger in public parking lots; and 2) while ELVs have two hours of free parking in public lots, a slow charge takes between six and eight hours, meaning that ELVs incur parking fees for four to six hours of their charging session. ELVs that use fast charging, with a typical charge time of one to two hours, are able to avoid parking fees entirely. This parking fee structure, combined with price regimes for charging services, makes fast charging cheaper than slow charging, despite the substantial extra grid costs that fast charging creates.

A strategy to address these pain points would be special parking policies for ELVs, which would include both fines for ICE cars that block EV charging stations and unlimited free parking for ELVs that are actively slow charging in public parking lots. Such a policy could also seek to increase the amount of public parking available at locations that are suitable for ELV charging, for example facilities with colocated driver services as described above or at or near major nodes in Shenzhen's goods distribution network.[47] This integrated planning of parking and charging system could help to minimize grid costs while also promoting higher utilization rates of ELVs.

Given that prices for parking in public lots are set by the municipal government of Shenzhen and given that it will be the primary party responsible for provision of additional parking, the government would be the main stakeholder responsible for implementing this strategy. However, collaboration with truck users, to identify high potential spots for new charger-equipped parking infrastructure (both on street and in lots) could enhance the effectiveness of government actions. Similarly, because government should only seek to provide free parking to ELVs that are actively charging, collaboration with charging station operators would also enhance government's ability to implement effective policy.

A SINGLE-STOP DATA PLATFORM FOR CHARGING SERVICES

The previous solutions explored ways to shape supply and demand of charging services in time and location to create an efficient ELV charging system. However, another opportunity exists to enhance the efficiency of the match between demand and supply for charging services in the current infrastructure and policy regime. This solution would target the pain points around difficulty in finding and paying for charging services in a seamless way across multiple providers.

Currently, there are more than 40 charging station operators in Shenzhen and most of them have created their own apps with associated payment services. However, due to the high fragmentation in supply of charging services and the variable quality of information on those apps, user experience is often poor. A portal with high-quality, real-time information on charger availability across providers would provide a better match between supply and demand for charging services, reducing the issues with queuing and lost productivity that exist in the market today. Over a longer timeframe, that portal could actively guide trucks to available chargers that are convenient to them. Given the real-time data that is being collected from both from trucks and chargers, the long-term ability to shape drivers' selection of charging stations, both through information availability and dynamic price signaling, is considerable. Combined with forecasts of electricity load at individual nodes in the distribution grid, and price signals to steer drivers away from nodes nearing capacity, such a platform could also enable effective ELV charging load management in real time. Over time, such a platform could even provide a scheduling functionality allowing drivers to book and prepay charging sessions at particular stations. This would both enhance truck and charging station utilization, while also providing grid operators with high accuracy load information hours in advance of its occurrence.

With the newly issued mandate for all chargers to share real-time data with the government, the foundation for such a platform already exists and is owned by the municipal government. However, given that the provision of such a platform would influence demand for charging services, and therefore charging station revenue and profitability, any action would need to be taken in close consultation and partnership with charging station operators to ensure fair and transparent competition. For that reason, such a platform would likely be implemented as a public-private partnership between municipal authorities and charging station operators. In the longer term, if load management for the distribution grid became a functionality of such a platform, Southern Grid would need to be brought into the partnership as well.

INNOVATIVE FUTURE OPPORTUNITIES FOR EFFICIENT DELIVERY OF CHARGING SERVICES

Multistory Parking and Charging

For highly trafficked locations in the urban core, limitations on land availability cause trucks to queue for charging services. However, as real estate developers realized long ago, that land constraint is two dimensional. That same realization, that going vertical can effectively provide more space, is also applicable to charging and parking in the form of charge towers. Multistory parking and charging can help overcome the problem of high land use cost faced by charging station operators. Take Penglong Tower at the 3rd Ring

Road in Beijing, for example. Its six-story smart-charging vertical parking garage can charge 43 EVs at the same time, despite the fact that the charging station only has eight ground-level parking spaces.[48] Expanding this type of infrastructure to ELVs could help alleviate land constraints on charging availability.

V1G

Unidirectional smart grid (V1G) is a single-direction, controlled charging technology between the grid and ELVs. V1G allows the grid to manage the charging time and power of ELVs to enable load management and peak shifting through remote, autonomous management of power discharge at individual charging stations. ELV users with charging needs can connect their EVs to smart chargers and input information such as time and duration of charging. After receiving that data, the grid remotely sends signals to turn on or off the connected chargers based on integrated information from all connected smart chargers in the context of real-time grid load. ELV drivers can select their willingness to accept curtailment under V1G strategies. Higher willingness to accept curtailment would be compensated with lower electricity prices. This model allows the grid to shift charging demand away from load peaks in real time, avoiding costly infrastructure upgrades.

Although V1G is already technically feasible, its application is still quite limited. In Shenzhen, several charging station operators, including Southern Heshun and X-charge, have launched Internet of Things (IoT)-based smart charging systems that enable simultaneous remote control of users and prices.[49] However, as with other demand management strategies discussed above, those capabilities have not been used in actual grid load management because of the lack of appropriate electricity pricing and corresponding incentive mechanisms for ELV drivers.

V2G

V2G is a bidirectional interaction technology between vehicles and the grid. It allows EVs to act as mobile energy storage units when they park, enabling the bidirectional flow of electric power between the grid and ELVs. An ELV can act as a grid load to get power through charging facilities when its battery is low, and can also act as a grid resource when its battery is full, providing power back to the grid both to shave peaks as well as to provide ancillary grid services such as frequency regulation or black start. Since ELVs are distributed all over Shenzhen, they have the ability to become a very valuable distributed energy resource. This smart grid technology not only provides extra income for ELV owners but also can enable the grid and charging station operators to work together to manage the grid in a lower cost, more intelligent manner.

At present, the application of this bidirectional smart charging technology in the grid is still in the research and small-scale testing stage globally. In Shenzhen, V2G research is ongoing. The Southern Grid Science and Technology Research Institute and the High-Tech Research and Development Center of the Ministry of Science and Technology are collaborating on research to advance the development of V2G technology.[50] In addition, the Shenzhen Power Supply Bureau completed the tendering process for its research and development tasks.[51]

However, there are still many barriers to be overcome for V2G technology to be widely used in the grid. First, frequent charging and discharging will shorten battery life. Therefore, creating appropriate compensation structures for V2G participants will be a major issue.[52] Second, fast charging and V2G are not compatible. Typically, a vehicle that is connected to a fast charger will only be an off-taker of power and will not remain plugged in after it is finished charging. As a result, the role of V2G in ELVs may be less than passenger EVs, with V1G being the dominant mode of smart charging for ELVs.

6 CONCLUSIONS

Image courtesy of: Wikimedia Commons, Zhang Yat Ming Sumsum

CONCLUSIONS

Over the last few years, Shenzhen has moved extremely quickly on the electrification of urban logistics—with admirable results. However, despite massive investment in charging stations, traditional planning and infrastructure deployment processes have been overwhelmed by the speed with which ELVs have been deployed. That has resulted in pain points for all industry stakeholders—carriers, drivers, leasing companies, charging station providers, and the distribution grid.

To alleviate the pain points resulting from rapid expansion of ELVs and associated infrastructure, Shenzhen can:

- Improve the way it selects locations for charging stations
- Variably price electricity both in time and location
- Deploy new technologies in grid management

These improvements can bring substantial benefits to the city, including a low-cost, efficient logistics system and a stable and resilient electricity grid.

However, some of these solutions require both technical and policy innovations, such as implementing smart grid technologies, creating EV specific tariffs that vary across time and location, and mobilizing big data for charging network planning. There is a lack of defined global best practices to guide implementation of these solutions. Just as Shenzhen has been a first mover in ELV deployment, it will also need to become a first mover and innovator in rolling out the policy frameworks, planning mechanisms, and technologies to effectively deploy charging for those ELVs.

Finally, Shenzhen is unique in that it has recorded and aggregated the entire experience of ELV adoption and use in minute detail. Shenzhen's willingness to pioneer the electrification of urban logistics as well as document and share its experience creates a clear path for other cities in China to follow. As those cities seek to replicate the outcomes Shenzhen has obtained, they will not have to go through the same learning-by-doing process that Shenzhen has gone through. Those cities will be able to directly implement policy packages designed in Shenzhen and, based on the data sets collected in Shenzhen and tools trained on those data sets, be able to create a blue print of an ELV charging network before trucks are deployed. That creates an excellent opportunity for other cities in China to replicate Shenzhen's outcomes at much lower cost.

APPENDIX

APPENDIX

EXHIBIT A1

Central and local subsidies for ELVs – 2013 to 2019

Year	Central government subsidy (RMB/kWh)			Maximum subsidy per vehicle (10,000 RMB)	Local government subsidy (RMB/kWh)			Maximum subsidy per vehicle (10,000 RMB)
	≤30 kWh	>30 kWh ≤50 kWh	>50 kWh		≤30 kWh	>30 kWh ≤50 kWh	>50 kWh	
2013	2,000	2,000	2,000	15	2,000	2,000	2,000	15
2014	1,900	1,900	1,900	15	2,000	2,000	2,000	15
2015	1,800	1,800	1,800	15	2,000	2,000	2,000	15
2016	1,800	1,800	1,800	15	2,000	2,000	2,000	15
2017	1,500	1,200	1,000	15	750	600	500	7.5
1/1/2018-2/11/2018	850	750	650	10	750	600	500	7.5
2/12/2018-6/11/2018	850	750	650	10	300	240	200	3
After 6/12/2018	850	750	650	10	425	375	325	5
After 3/26/2019	350			5.5	0			0

EXHIBIT A2

Shenzhen Public Chargers Electricity Rates

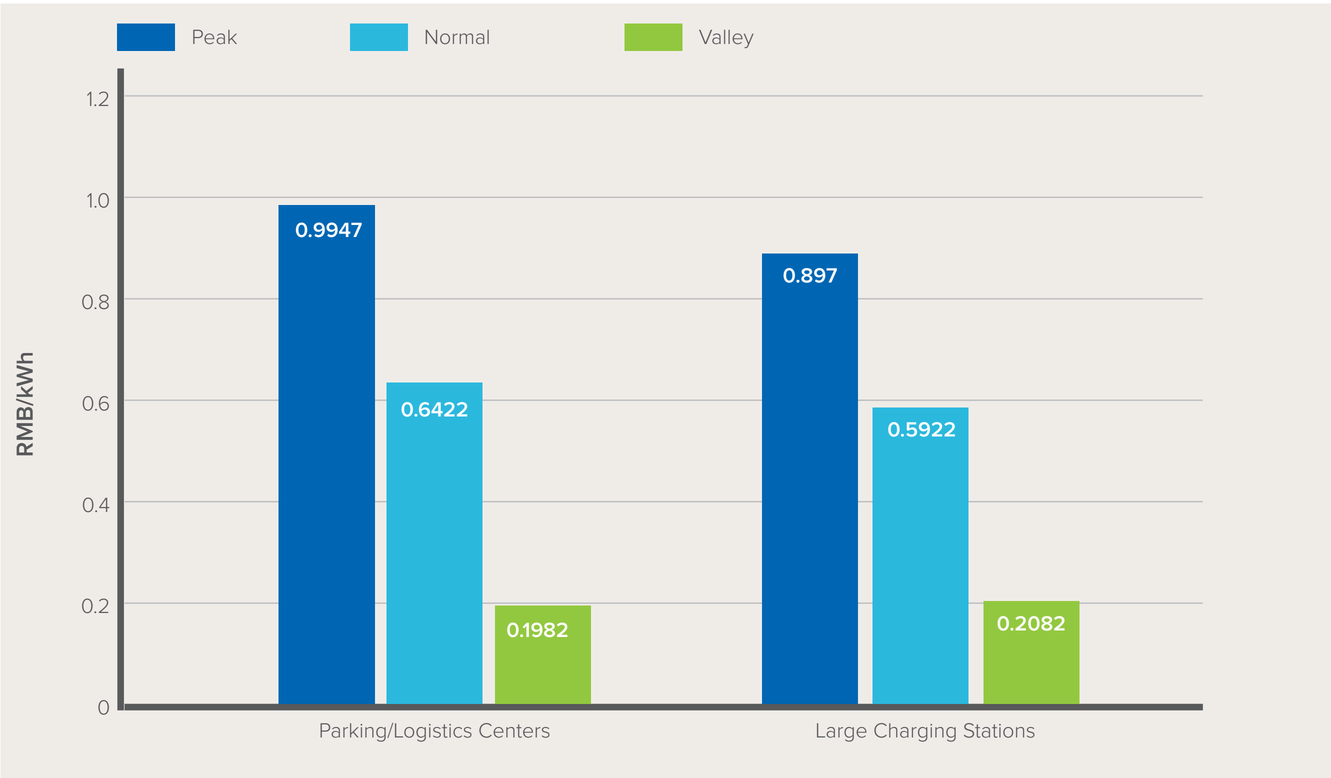


EXHIBIT A3

Shenzhen Residential Electricity Rates

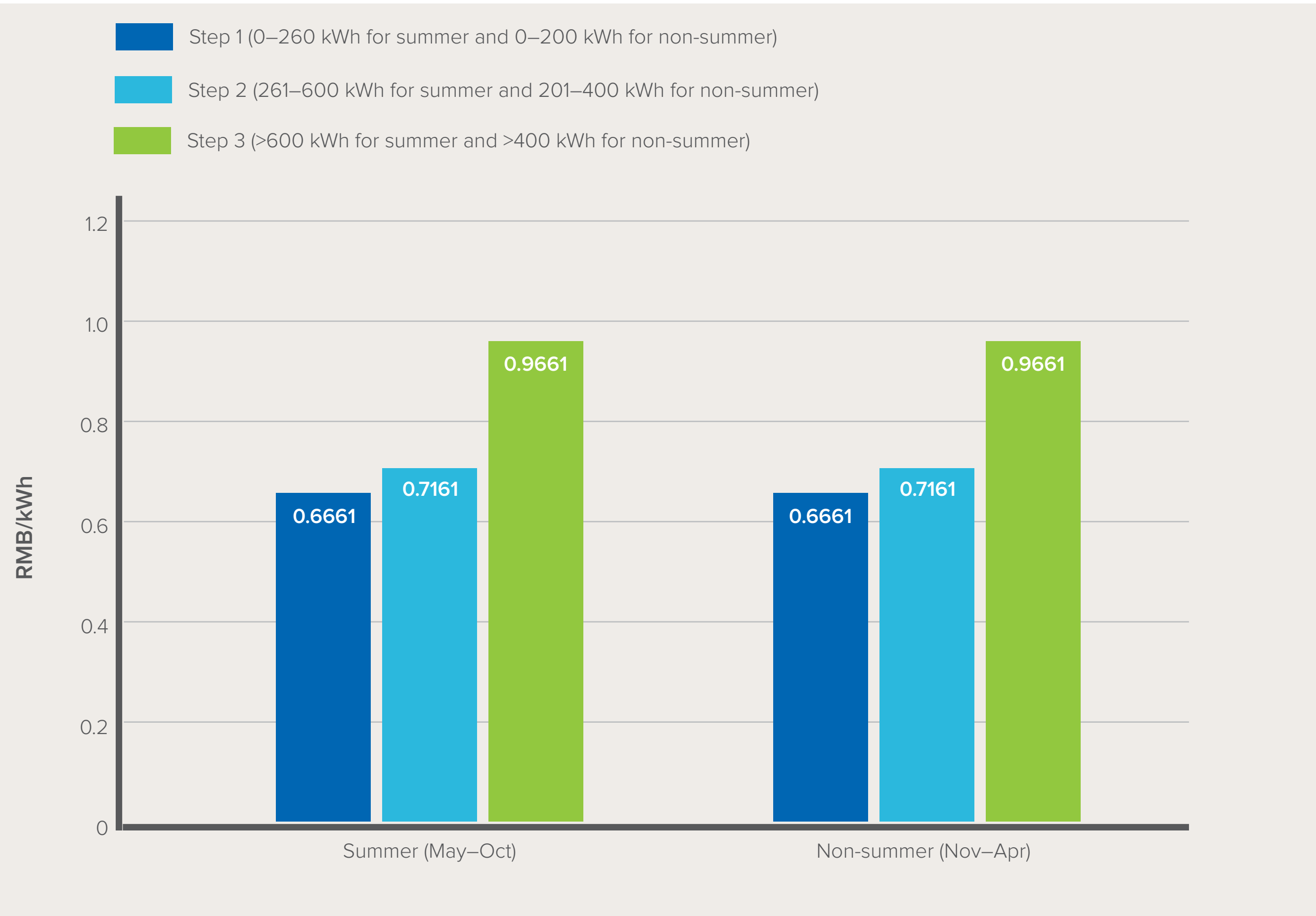


EXHIBIT A4

Shenzhen Industrial and Commercial Electricity Rate

Consumption Category	Industry & Commercial per kVA per month	Base Fee	Electricity Rate (RMB/kWh)														
			10 kV high			10 kV low			20 kV			110 kV			>220 kV		
			Peak	Normal	Valley	Peak	Normal	Valley	Peak	Normal	Valley	Peak	Normal	Valley	Peak	Normal	Valley
High Consumption 101–3,000 kVA (RMB/kVA)	<250 kWh	24	1.0207	0.6682	0.2242	1.0457	0.6932	0.2492	1.0147	0.6622	0.2782	0.9957	0.6432	0.1992	0.9707	0.6182	0.1742
	>250 kWh		1.0007	0.6482	0.2042	1.0257	0.6732	0.2292	0.9947	0.6422	0.1982	0.9757	0.6232	0.1792	0.9507	0.5982	0.1542
High Demand >3,001 kVA (RMB/kW)	<400 kWh	44	0.9230	0.6182	0.2342	0.9480	0.6432	0.2592	0.9170	0.6122	0.2282	0.8980	0.5932	0.2092	0.8730	0.5682	0.1842
	>400 kWh		0.9030	0.5982	0.2142	0.9280	0.6232	0.2392	0.8970	0.5922	0.2082	0.8780	0.5732	0.1892	0.8530	0.5482	0.1642
Others						1.1075	0.8203	0.2459									

EXHIBIT A5

Shenzhen Residential Electricity Rate

Category	User Group	Season	Step	Electricity Used (kWh)	Price (RMB/ kWh)
Residential Electricity Rate	Separate Meter User	Summer (May–October)	1	0–260	0.6661
			2	261–600	0.7161
			3	>600	0.9661
		Non-summer (November–April)	1	0-200	0.6661
			2	201–400	0.7161
			3	>400	0.9661
	Grouped Meter User				0.7031

ENDNOTES

ENDNOTES

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