ENERGY FOUNDATION
能源基金会

PUTTING ELECTRIC LOGISTICS VEHICLES TO WORK IN SHENZHEN

Infrastructure Volume: Enabling ELV Utilization through Well-Planned Charger Deployment

BACKGROUND | POLICY | INFRASTRUCTURE | VEHICLE QUALITY | BUSINESS MODEL | SUMMARY

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; Oakland, California; Washington, D.C.; and Beijing.

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MAJOR PARTNERS

Shenzhen Electric Vehicle Operating Association

Shenzhen Electric Vehicle Operating Association engages in six sectors including public transportation, taxi, logistics, rental, charging, and technical services and establishes communication platforms for government and enterprises, organizes industrial investigations and key discussions, develops industrial standards and specifications, and participates in policymaking. It strengthens the integration and cooperation between upstream and downstream players of the new energy vehicle industry chain, and promotes the healthy and orderly development of the new energy vehicle operation industry in Shenzhen.

National Engineering Laboratory for Electric Vehicles

Authorized by the National Development and Reform Commission in 2008, the National Engineering Laboratory for Electric Vehicles was established on the basis of the Electric Vehicle Engineering Technology Center of Beijing Institute of Technology. The National Testing and Management Platform for New Energy Vehicles built by the Laboratory provides data support for the research of new energy vehicles technology and the making of industrial policies.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Utilization is an important metric in benchmarking the ability of an electric logistics vehicle (ELV) to replace its internal combustion engine (ICE) counterpart. As used in this report, utilization refers to the amount of productive work a commercial vehicle can perform over a given time period. The higher utilization an ELV has, the more revenue-generating work it can perform and the more savings it accrues from its lower fuel and maintenance costs. Both of these increase the vehicle's attractiveness to fleet operators and support further electrification of the urban logistics fleet.

In China, as in many regions of the globe where logistics electrification has emerged, ELVs still have higher up-front purchase prices and lower utilizations than ICE vehicles.[1] This results in a total cost of ownership (TCO) disadvantage compared with ICE vehicles. As the adoption of electric vehicles (EVs), including ELVs, has increased, the Chinese national government and provincial and municipal governments have begun phasing out up-front purchase subsidies for electric vehicles. This has resulted in decreased ELV cost-competitiveness compared with ICE vehicles. However, in Shenzhen, a high-tech metropolis that leads the world in electric vehicle deployment, the municipal government has developed a set of innovative subsidies and investment policies to increase the viability of electric vehicles for use in logistics applications.

One such policy, the operational subsidy, is the focus of the *Policy Volume* of this report series and is a measure to incentivize higher ELV utilization to close the TCO gap with ICE vehicles. This report, *Infrastructure Volume*, explores a different policy focus in Shenzhen concerning the development of charging infrastructure capable of supporting and encouraging further ELV adoption.

Well-planned charging infrastructure for logistics vehicles can:

- Reduce queueing times at stations caused by uneven supply and demand for charging
- Eliminate the need for drivers to deviate from their operational routes to find chargers
- Provide the ability for vehicles to charge during periods of pre-scheduled down-time, such as lunch breaks
- Allow ELVs to access more regions of the city, thus increasing the potential for logistics electrification
- Eliminate drivers' range-anxiety
- Reduce perceived risk of ELV adoption for a logistics business

The aim of this report is to analyze charging networks based on these criteria and we begin the report by exploring the status quo of electric logistics vehicle charging in Shenzhen. Through analysis of operational data and surveys with charging station operators, logistics fleets, and other stakeholders, we seek to understand the unique charging preferences and patterns of Shenzhen's maturing ELV market. In doing so, we identify crucial gaps and opportunities for growth that can better align charging systems with the needs of logistics vehicles. Lastly, we offer some recommendations on the planning and construction of chargers in Shenzhen to meet the specific demands of ELVs and further Shenzhen's clean transportation goals.

By analyzing Shenzhen's experience, we hope to provide a roadmap to enable other cities to follow Shenzhen's path as a global first mover.

Summary of Key Research Findings:

1. The charging stations that ELVs use in Shenzhen fall into three primary categories:

- Private chargers at logistics warehouses
- Other private chargers, primarily located at industrial or commercial facilities
- Public chargers that are shared with other EV segments in Shenzhen

Broadly these locations represent charging needs at different points along a vehicle's duty cycle: where it is parked overnight, at the start and end of its routes, and along operational routes.

2. Most ELVs do not strictly charge at warehouses overnight using slow chargers, which is thought to be the typical charging model for logistics vehicles. Many vehicles use public fast charging and, where warehouse charging is used, it is often fast charging and not always overnight.

3. Public fast charging is a significant component of ELV charging. Almost all new market entrants heavily rely on fast charging, signaling both an increased supply of and demand for faster charging speeds for logistics vehicles. This also suggests that sufficient public fast charging is a necessary condition for enabling large segments of the urban logistics market to electrify.

4. Land leases for charging stations in needed areas are often prohibitively expensive, while the grid connections and upgrades needed for private fast-charging installations are difficult to obtain. The complicated and expensive process of obtaining land leases and grid connections for charging installations can be a barrier to transitioning to electric vehicles.

5. The industrial districts of Longgang, Longhua, and Baoan have less public charging infrastructure proportional to ELV charging demand. Current policies in Shenzhen have mostly focused on satisfying charging demand for the passenger and taxi EV markets. This leads to more public infrastructure in the more densely populated districts of Futian and Nanshan.

BACKGROUND

ELV ADOPTION DECISIONS ARE BASED ON HOW WELL CHARGING INFRASTRUCTURE SATISFIES LOGISTICS NEEDS

A logistics company's decision to electrify its fleet comes down to whether or not the new electric vehicles will provide the same or greater benefit than traditional gasoline alternatives. ICE vehicles benefit from a lower up-front cost, fast refueling times, and long ranges, but suffer from high and uncertain operating costs due to their reliance on high and volatile gasoline prices and constant maintenance needs. On the other hand, electric vehicles are much cheaper to operate due to more efficient engines, low and relatively stable electricity prices, and lower maintenance costs. However they have a higher up-front cost, shorter range, and require longer refueling (charging) times.[2]

One crucial factor that keeps ELVs from capitalizing on this operating cost advantage and surpassing ICE vehicles in logistics fleet decisions is the lack of a sufficient charging network. If an ELV has to spend extra time queueing for chargers, deviating from operating routes in search of chargers, or charging when it would otherwise be serving customers, it loses its revenue-generating potential. It additionally adds uncertainty for companies that differentiate themselves from their competitors based on punctuality and reliability.

To make ELVs a more attractive proposition for fleet operators, they should have access to a charging system that is aligned with their needs. This means one that allows for charging during pre-existing down-times, minimizes time lost to queuing and off-route driving to charging stations, and maximizes their ability to accomplish productive economic work.

SHENZHEN, CHINA, HAS A LONG HISTORY OF SUPPORTIVE POLICIES FOR EV INFRASTRUCTURE

Over the past decade, the City of Shenzhen has designed and implemented charging infrastructure policies to support its burgeoning EV market. In 2010, to accelerate the development of what it calls its "new energy industry," Shenzhen implemented the Revitalization and Development Plan for the New Energy Industry in Shenzhen. This plan set targets for new energy vehicle (NEV) adoption and established a plan for construction of charging infrastructure.[3]

As the plan was implemented and the number of NEVs on Shenzhen's roads increased from less than 1,000 in 2010 to more than 360,000 in 2019, the policy focus shifted to support the build-out and effective use of charging infrastructure.[4] As discussed in the Background Volume of this report series, *Setting the Stage for Full Utilization of ELVs in Shenzhen,* key policy moves to support charging station development include:

1. Charger construction subsidies

In 2013, the Shenzhen municipal government instituted a program to subsidize the high costs of charger construction and spur growth in the charging market. From 2013 to 2015, the subsidy covered 30% of up-front cost of each charger and had few requirements for eligibility.[5]

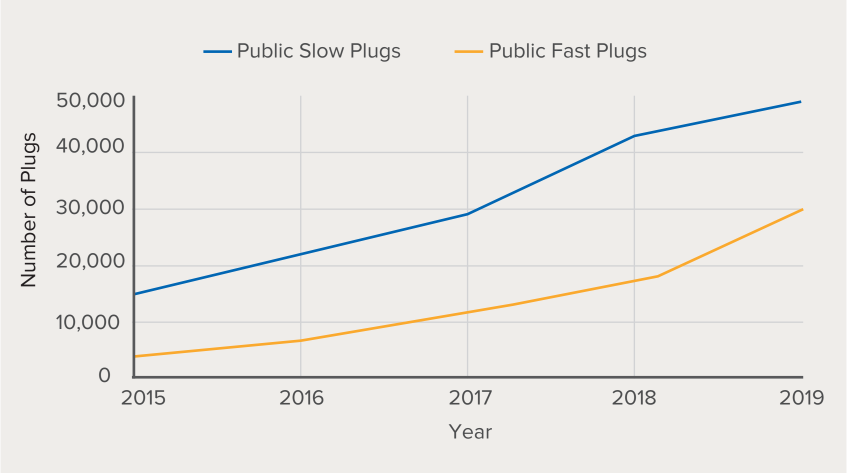
In 2016, with over 100 registered charging operators in Shenzhen and increasing complaints of poorly constructed stations, the government raised the power requirement for charging station operators. Regulations were changed to stipulate that only operators with total power of 8,000 kilowatts (kW) or more were eligible for the subsidy.[6] The higher threshold incentivized larger, more experienced station operators capable of building well-functioning stations at scale.

Around the same time, Shenzhen implemented a tiered subsidy structure, giving more support to direct current (DC) than to alternating current (AC) chargers to compensate for the higher capital costs associated with public DC fast charging. It also created a subsidy advantage for charging installations above 40 kW.[7] As a consequence of these policies, construction of infrastructure has soared (see Exhibit 1). At the end of 2019, there were 30,000 public fast charging plugs and 50,000 public slow charging plugs in the city.[i]

[i] Private chargers number statistics are not currently publicly available.

EXHIBIT 1

Public Fast and Slow Charging Plug Growth Over Time



In recent years, Shenzhen has reduced the subsidy amounts to reflect the cost improvements the charging industry has made over the last decade. The specifics of how that policy evolved over the years is shown in the following table.

EXHIBIT 2

Subsidies for Charging Facilities in Shenzhen

Year	Power Requirement	Subsidy Amount	Source
2013-2015	N/A	30% of the investment	Promotion and Application of New Energy Vehicles in Shenzhen (2015)
2016	Registered charging operator with total power capacity of 8,000 kW	DC: ¥300/kW AC: ¥150/kW	Promotion and Application of New Energy Vehicles in Shenzhen (2016)
2017	Registered charging operator with total power capacity of 8,000 kW	DC: ¥600/kW AC: ¥300/kW	Financial support policy for Promotion and Application of New Energy Vehicles in Shenzhen (2016)
2018	Registered charging operator with total power capacity of 8,000 kW	DC: ¥600/kW AC>40kW: ¥300/kW AC<40kW: ¥200/kW	Promotion and Application of New Energy Vehicles in Shenzhen (2018)
2019-2020	Registered charging operator with total power capacity of 8,000 kW	DC: ¥400/kW AC>40kW: ¥200/kW AC<40kW: ¥100/kW	Promotion and Application of New Energy Vehicles in Shenzhen (2019-2020)

Source: Development and Reform Commission of Shenzhen Municipality

2. Preferential electricity pricing for charging stations

In addition to charger construction subsidies, the Shenzhen municipal government has instituted preferential electricity rates for charging stations to reduce costs to charging operators and drivers. According to the rules of the Development and Reform Commission of Shenzhen Municipality, since July 2018, certain public charging facilities connected directly to the grid are eligible for large industrial and commercial electricity prices, as opposed to residential or normal commercial and industrial rates.

To qualify for preferential electricity prices, the installation must have at least 150 kW of total capacity, have three or more chargers, and have a land lease agreement for at least three years. This is different from the qualifications for charger construction subsidies and these thresholds encourage construction of larger charging stations that benefit from economies of scale by spreading the high fixed costs of installation over more charging stations.

The large industrial and commercial rates these chargers qualify for are between ¥0.17 and ¥1.03 (US$0.025–$0.151) per kilowatt-hour (kWh), depending on the time of use. This is lower than residential electricity rates, which are between ¥0.67 and ¥0.97 (US$0.097–$0.141) per kWh, depending on how many kWh each unit uses each month.[8]

3. Regulated service fees

In order to ensure that charging operators do not capture all of the benefit from lower rates and pass on some cost savings to the drivers, Shenzhen has regulated the profit that charging stations can earn. Specifically, a station operator may only charge for the cost of electricity it sells plus a regulated service fee. The service fee that operators charge is capped at ¥0.8 per kWh (US$0.12 per kWh). With all of these policies in place, both the charging operator and the driver see increases in their bottom-lines. Charging operators benefit from lower electricity rates and subsidized construction, while the drivers benefit from lower electricity prices and capped fees.

4. Free parking for charging vehicles

Similar to other major metropolitan cities, curbside and other public parking in Shenzhen is hard to come by and costs can be prohibitively high when it is available. To prevent the addition of parking fees on top of public charging rates, and create a more convenient experience for EVs, the Shenzhen municipal government has issued several regulations on the price of parking for EVs.

The Notice on Improving the Charging Policy for Vehicle Parking Services in Shenzhen, issued by the Development and Reform Commission of Shenzhen Municipality in 2017, states that EVs charging in public parking facilities can enjoy two hours of free parking each day.[9] Those charging on the curb can enjoy one hour of free parking.[10] With much public charging in Shenzhen consisting of fast charging, often at 50 kW or more, one to two hours is often enough to recharge an EV to full capacity.

DESPITE A MATURE CHARGING NETWORK, THERE IS AMPLE OPPORTUNITY TO OPTIMIZE INFRASTRUCTURE TO BETTER SUIT THE NEEDS OF ELVS

While Shenzhen has one of the world's most developed public fast charging networks, throughout the team's research surveys and interviews, logistics fleets and charging station operators in Shenzhen stated that charging infrastructure is still largely insufficient to support a complete electrification of logistics vehicles. Interviewee feedback about the current network included:

- Queueing at some public charging stations is common, making servicing customers in certain areas unreliable.

- There are gaps in the distribution of public charging infrastructure, making some routes better suited for ICE vehicles with longer ranges and the ability to more widely refuel across the city.

- Private charging infrastructure installations are hindered by high land leasing costs and lengthy, difficult, and sometimes impossible grid approvals and connections.

METHODOLOGY

Electric vehicle charging in urban areas is a complex problem that requires a deep understanding of the experience of individuals and the underlying systems. Our approach to evaluating these issues complements stakeholder interviews with robust analysis of publicly available datasets available through Baidu and private telematics data from the National EV Data Platform, a nationwide vehicle monitoring platform facilitated by the Beijing Institute of Technology.

Due to the sensitive nature of the data and limitations on what data is accessible, the research team inferred the locations of charging stations from telematics data in order to analyze ELV charging patterns. By using unsupervised machine learning clustering techniques, ELV charging events were grouped together to locate charging stations. From these grouped events, locations, daily load curves, and power distributions could all be derived and analyzed.

In order to understand and classify the locations of charging stations within the city, the proximity of a charging station to different points of interest was calculated. A charging station was assigned to be proximal to a point of interest if it was found within a 100 meter radius of that point of interest. With this approach, charging patterns for ELVs could not only be analyzed for each station, but also for each category of point of interest. Thus, we could understand what types of facilities provided charging to ELVs and optimize infrastructure recommendations accordingly.

There is some unavoidable amount of uncertainty introduced through clustering of charging events and assignment to points of interest. Through analytical validation and confirmation of broad-scale results with knowledgeable stakeholders, the research team is confident in the accuracy of these results, despite these uncertainties.

Alongside the data analysis, the research team verified and added to results by conducting research interviews with local transportation enterprises and charging station operators in Shenzhen. Partners included Shenzhen Electric Vehicles Operation Association and interviewees included DST Car Rental, Zhongdian Luyuan, Xinneng Logistics, SF Express, JD, TELD, Potevio New Energy, and Fortune EV Traffic.

ANALYSIS RESULTS

Based on data analysis and information from stakeholder interviews, the research team concluded three major findings relevant to the development of charging infrastructure for ELVs in Shenzhen:

1. Logistics charging predominately occurs at logistics warehouses, public stations, and other commercial or industrial facilities concentrated in the industrial districts of Longgang, Baoan, and Longhua.

2. In aggregate, ELVs in Shenzhen do not rely as heavily on private, overnight slow charging as is typically expected of a commercial electric vehicle.

3. Public fast charging is a crucial part of ELV charging and is becoming increasingly relied upon.

THE GEOGRAPHY OF ELV CHARGING IN SHENZHEN

1. Major locations of ELV charging

By analyzing the charging patterns of logistics vehicles registered in Shenzhen, we see that the locations at which this population charges fall into one of three categories (see Exhibit 3):

- Public charging stations, often co-located with ancillary services like shops and restaurants

- Logistics warehouses, where vehicles are frequently stored and charge overnight

- Other private facilities, including industrial parks and commercial locations, primarily representing pick-up and drop-off locations for goods deliveries

EXHIBIT 3

Major Location Types Used by ELVs for Charging

Example charging station locations that resulted from the analysis. From top to bottom, figures show a large public charging station, a charging station located on premise at a logistics facility, and a charging station located in an industrial park.

2. Distribution of charging facilities

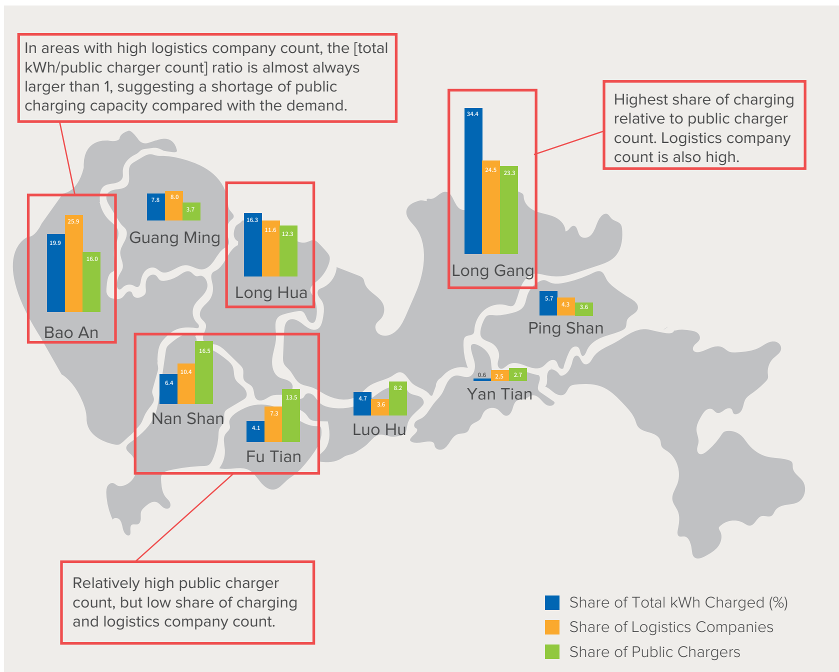
Results from the analysis of 2019 data identified 6,893 total charging stations serving the Shenzhen ELV population of 41,138 vehicles registered on the data collection platform. Of those stations, about 1,200 were known public charging stations and 1,475 were associated with logistics warehouses. Of the remaining 4,210 chargers, many were associated with industrial parks, commercial districts, and other points of interest likely to generate freight loading and unloading activities.

However, due to the very large number of commercial and industrial facilities in Shenzhen it is impossible to know whether those chargers were intentionally built to serve a particular facility. For that reason, we have aggregated them into a group that broadly represents private charging not associated with a warehouse.

On a district level, over 70% of the ELV charging analyzed occurred in the highly industrialized districts of Longgang, Baoan, and Longhua, which have high densities of logistics warehouses and industrial parks. However, these three regions are home to only about half of the public charging stations in Shenzhen. The remaining public charging stations are mostly concentrated in Nanshan and Futian Districts, two of the most populous districts in Shenzhen, both of which have relatively small concentrations of logistics charging. This reflects the fact that Shenzhen's charging policy developed to first serve the needs of passenger and taxi vehicles and only later began to make considerations for logistics charging.

EXHIBIT 4

Total ELV Charging Volume, Percentage of Logistics Warehouses and Public Chargers in Each District in Shenzhen



SLOW VERSUS FAST CHARGING: PUBLIC AND PRIVATE

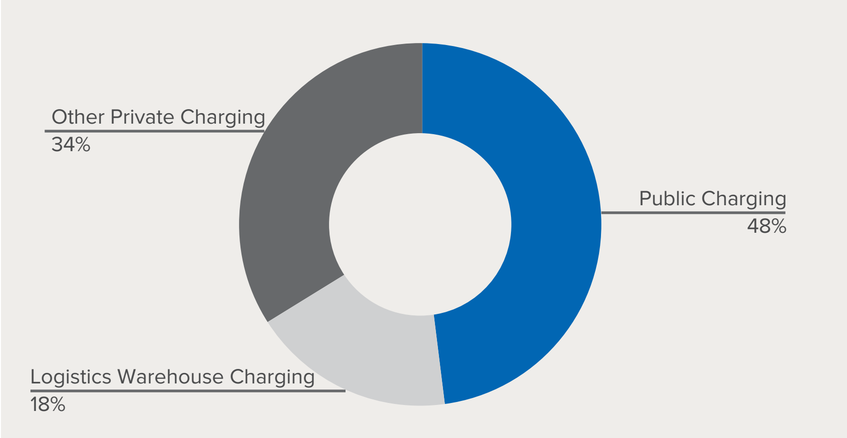
Private slow charging, during after-work hours, is often thought to comprise the bulk of commercial and logistics energy needs, with public charging only filling the unmet gaps. In these operational models, public charging is only used when absolutely necessary, because private, slow-charging installations are more reliably available, less capital intensive to install, and easier to align with time-of-use electricity rates. Through our analysis, we find that the reality of ELV charging in Shenzhen is not so simple. Instead, ELVs employ numerous operational models that utilize different ratios of private and public charging at different power levels and times of the day.

1. ELVs use both public and private charging significantly

Results show that ELVs do not lean on private, slow-charging stations for the vast majority of their charging needs—in fact logistics facility charging accounted for only 18% of total energy for the ELV system. Private charging as a whole, including both commercial and industrial charging and logistics warehouse charging, accounted for just over half of the energy consumed by ELVs in 2018 and 2019; the other half came from public charging stations (Exhibit 5).

EXHIBIT 5

Share of Total kWh Charged in Three Major Types of ELV Charging Stations during 2018 and 2019



2. Private charging stations are not all slow and overnight

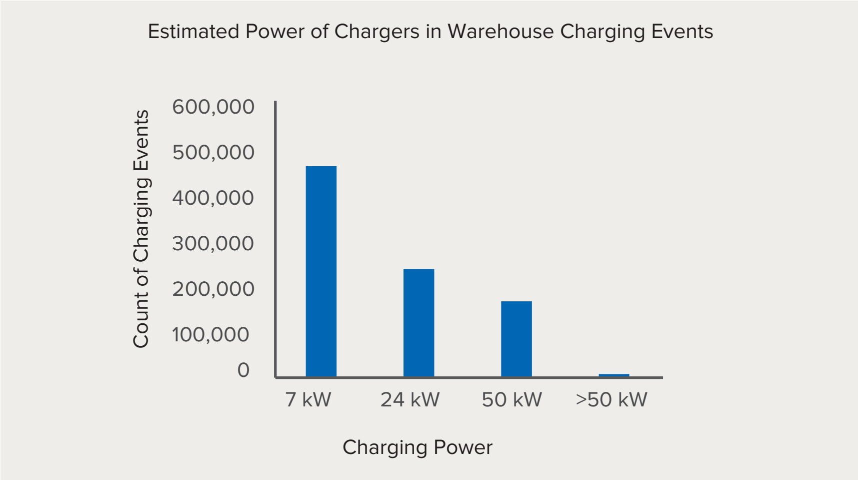
While ELVs perform significant amounts of slow charging at private charging stations, they also often utilize fast charging at private stations. Exhibit 6 displays the average power of charging events occurring at different private charging locations and the estimated power of chargers providing that electricity.

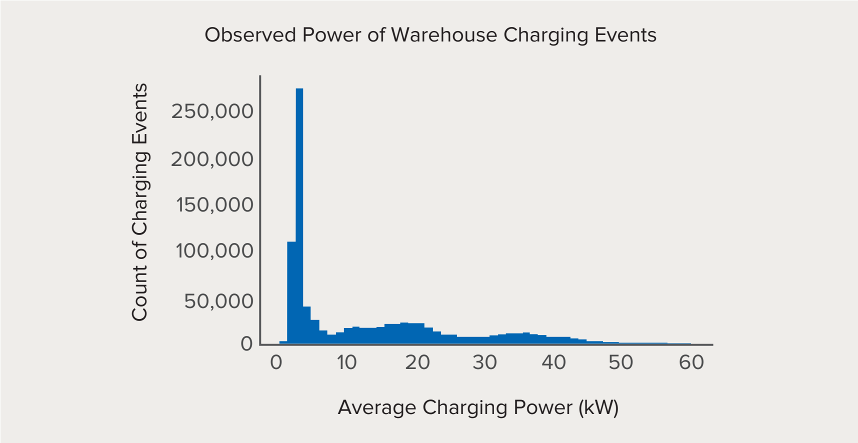
Given that the research team only had access to vehicle telematics data, we could only calculate average power of a charge event. Many factors, especially a high battery state of charge at the beginning of a charge event and use of managed charging, can cause the average power of a charging event to be less than the actual capacity of the charger. For that reason, we have aggregated charge events into estimated powers of the charger serving them, as well as presenting average observed charging power during the charging event.

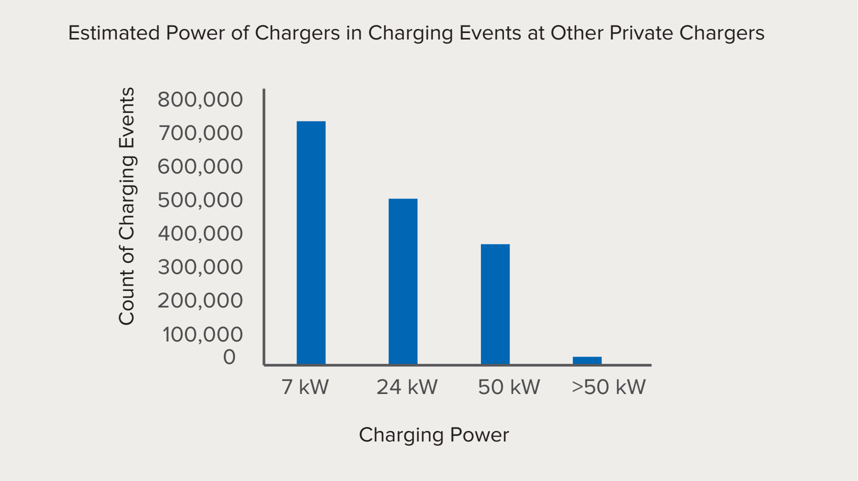
As evidenced by the exhibits below, private charging stations are composed of more than just slow-charging stations. While large amounts of 6–7 kW slow charging exist at both categories of private chargers, significant amounts of 24 and 50 kW charging also exist at these locations. Through research interviews, the team learned that large logistics companies, like Jingdong and Shunfeng, coordinate with charging operators to have fast chargers installed at or near their industrial or logistics facilities. This is often an attempt to benchmark charging speeds against the refueling times of ICE vehicles.

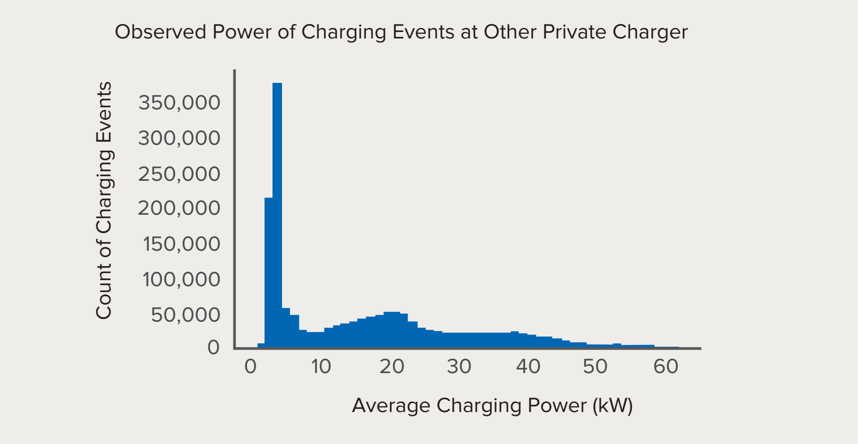
EXHIBIT 6

Non-Public Charging Power Distributions





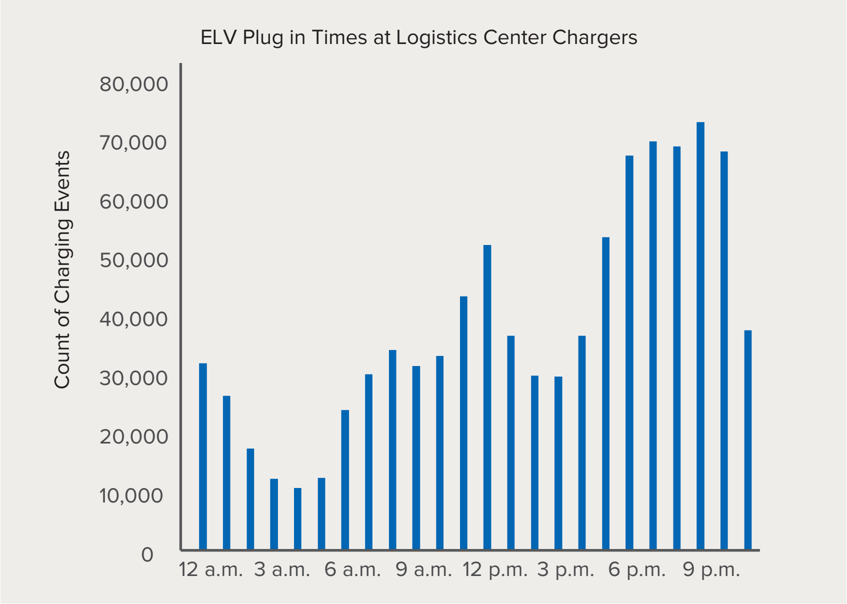


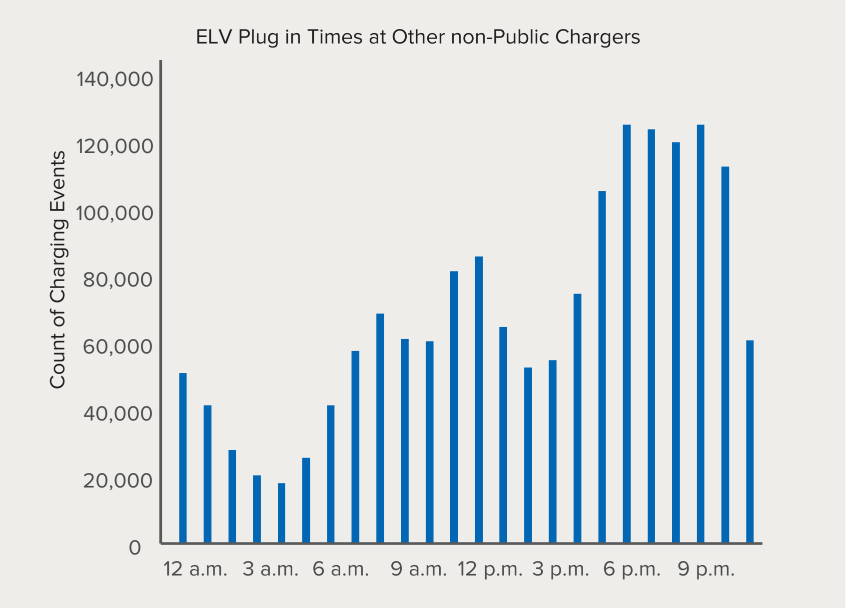


Further exploration of the daily charging loads at these private charging locations shows that the majority of private charging occurs after 6 p.m., as expected. However, there are prominent charging peaks at noon, when most drivers take lunch breaks, and in the early morning, before the workday starts. Through interviews, we have confirmed that ELV fleet vehicles often attempt to align charging with dwell-times, like lunch breaks, throughout the day, in order to avoid charging during operating hours. The early morning peak is less obvious, and is likely due to vehicles fast charging before the workday begins—potentially while vehicles are being loaded or while drivers eat breakfast.

EXHIBIT 7

Private Charging Hourly Load Curves





THE VITAL ROLE OF PUBLIC FAST CHARGING

1. Public fast charging is a significant component of ELV charging in Shenzhen

As evidenced by the policy review in the background section of this insight brief, public fast charging has been the main focus of Shenzhen municipal policy in recent years. Electricity prices and subsidies encourage the construction of stations with large amounts of fast charging to satisfy the demands of passenger EVs, electric taxis, electric transportation network company (TNC) vehicles, and ELVs. A good example of this trend is the Minle Public Charging station, located close to the Shenzhen Metro. To our knowledge, this is the largest public charging station in the world.

EXHIBIT 8

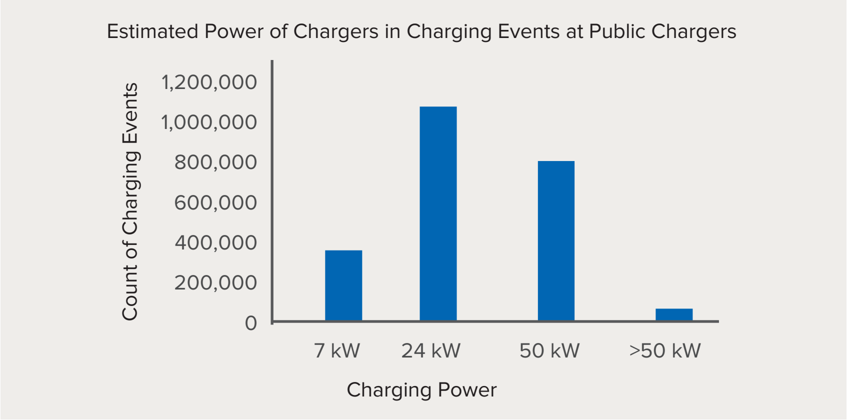
Minle Public Charging Station in Shenzhen

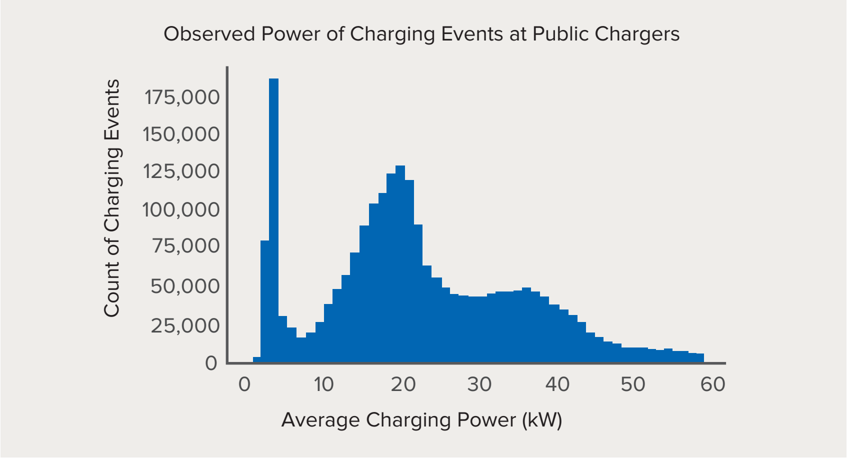
Minle Station in Shenzhen operates over 600 fast chargers and services close to 5,000 EVs per day.

Data analysis shows ELVs' strong use of public fast charging, a phenomenon confirmed in research interviews. The roughly 50% of ELV charging that occurs at public charging stations overwhelmingly occurs at faster speeds, as shown in Exhibit 9.

EXHIBIT 9

Public Charging Power Distributions

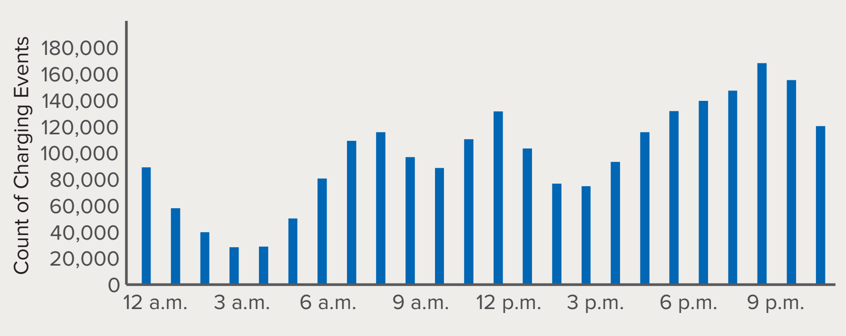




In contrast to the above analysis of private ELV charging, public charging experiences much more prominent peaks during the morning and lunch-time hours; those peaks are nearly as busy as the evening peaks. These patterns can again be understood by the fact that ELV drivers prefer to charge during periods when they are not servicing customers and therefore not losing potential revenue. Large, public fast-charging stations in Shenzhen are also typically collocated with auxiliary leisure and food services making them more appealing for this mid-day lunch-time charging.

EXHIBIT 10

Distribution of Public ELV Charging Events over the Day



2. The past few years have seen a trend toward more fast charging

Comparing ELV charging data between 2018 and 2019 shows an increasing prevalence of fast charging, in line with stakeholder interviews. On the supply side, a combination of policy that prefers public fast charging, improving charger economics, and increased customer demand for fast charging have led to accelerated deployment of fast chargers available for ELV usage. On the demand side, ELV operators, in an attempt to have charging times on par with ICE refueling times, are demanding more fast charging.

This trend is also apparent in the average power distributions of ELV charging events. From 2018 to 2019, the ratio of fast to slow charging increased dramatically (Exhibit 11).

EXHIBIT 11

Share of ELV kWh Dispensed through Fast and Slow Charging

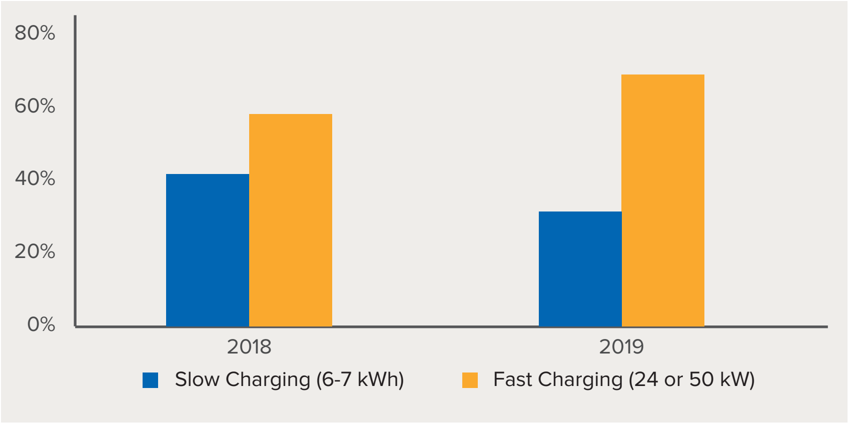
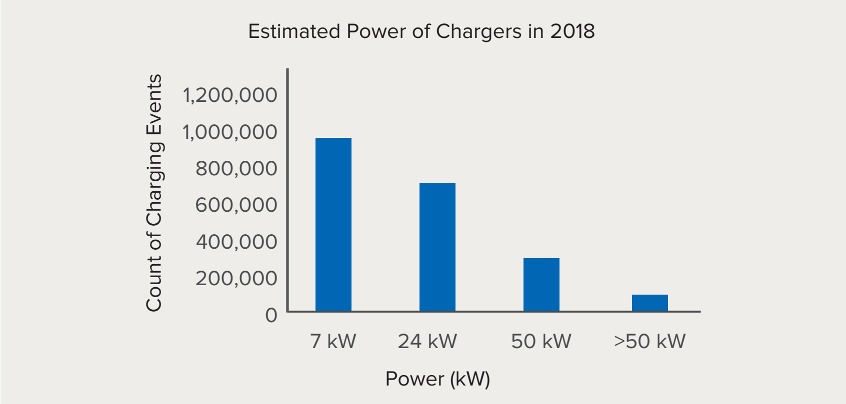
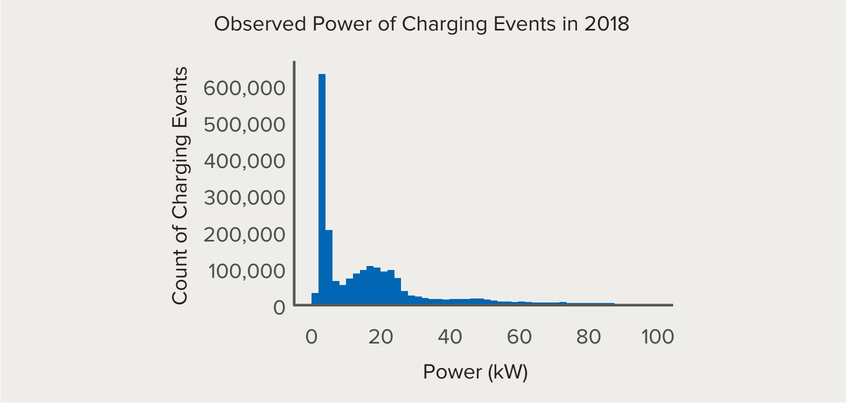
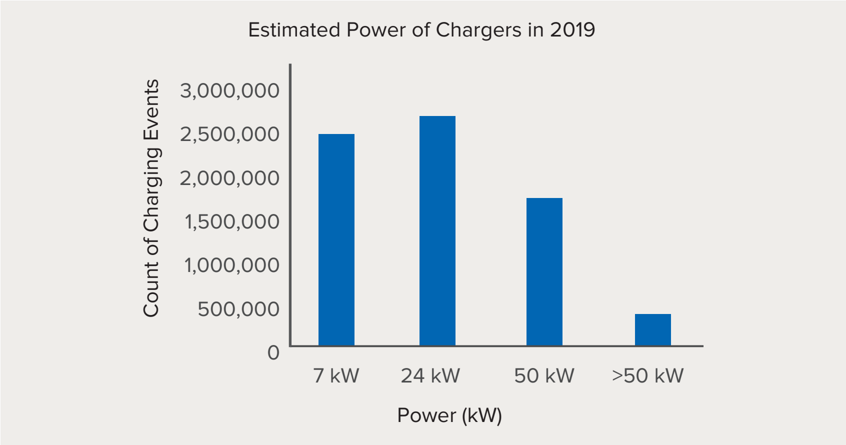


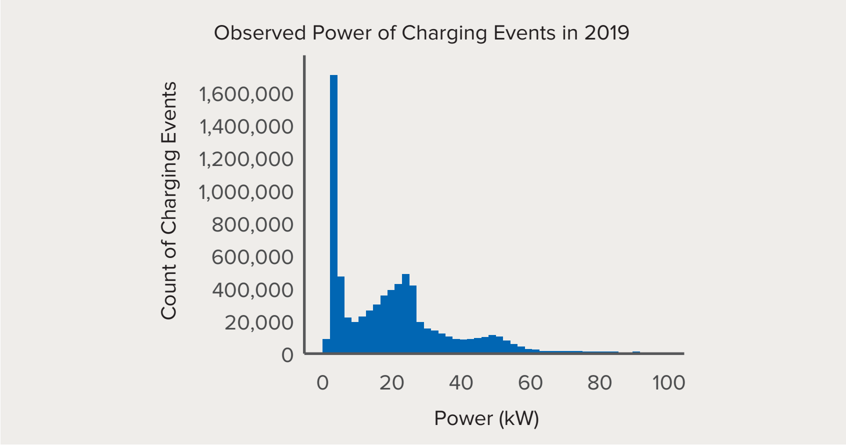
EXHIBIT 12

Evolution of Charging Event Power and Estimated Charger Power from 2018 to 2019






Estimated Power of Chargers in 2019
Count of Charging Events
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
7 kW
24 kW
50 kW
>50 kW
Power (kW)


Observed Power of Charging Events in 2019
Count of Charging Events
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
20,000
0
0
20
40
60
80
100
Power (kW)

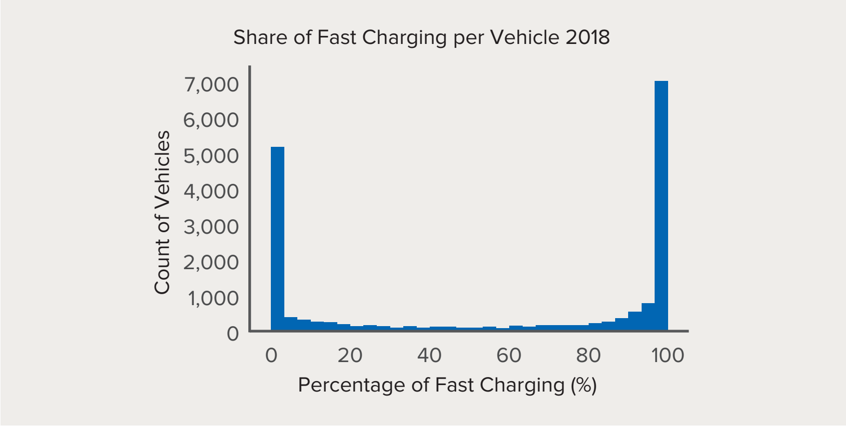
By analyzing the relative amounts of fast and slow charging on a vehicle basis, we can also understand how vehicle charging patterns are evolving over time. Above, we discussed the clear conclusion that fast charging is rapidly gaining market share. Two related issues are how individual vehicles use fast and slow charging and what has driven the growth in fast charging in 2019.

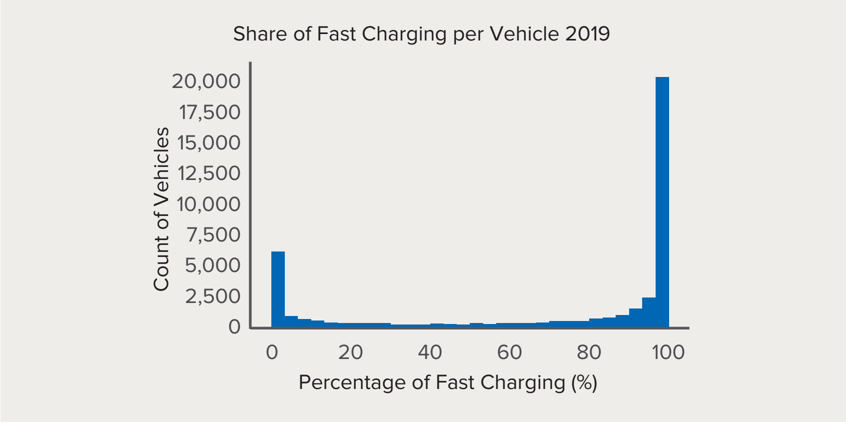
First, individual vehicles either dominantly fast charge (more than 90% of charge events for a vehicle have observed power of over 8 kWh) or slow charge (observed power of under 8 kWh). Only a small portion of the vehicle population uses both fast and slow charging together.

Second, the growth in fast charging demand between 2018 and 2019 was not driven by increased mixed use of fast and slow charging, but by an influx of vehicles to the data platform that exclusively fast charge. In 2018, roughly 5,000 vehicles slow charged only, while 7,000 fast charged, and the remaining vehicles performed some combination of the two. In 2019, while the number of dedicated slow charging vehicles remained relatively fixed from the previous year, the number of dedicated fast-charging vehicles increased to 20,000. This represented a 180% increase.

EXHIBIT 13

Shenzhen ELV Share of Fast Charging per Vehicle





Our interpretation of this growth, supported by stakeholder interviews, is that vehicles that were able to slow charge were among the first to electrify. Other, more challenging use cases have become increasingly viable to electrify as widespread availability of public fast charging emerged. This is especially notable among small logistics firms and individual drivers who find business on the spot market or load matching apps such as Huolala (the Chinese freight equivalent of Uber or Lyft).

Interviews and surveys with local transportation enterprises and charging station operators in Shenzhen clarified how a virtuous circle in charging prices led to these second-mover markets rapidly electrifying. In the early stages of logistics electrification in Shenzhen, there was a huge difference between the cost of fast and slow charging. Additionally, demand for high charging speeds by the vehicles charging at night was low, leading to a greater number of slow chargers during the initial period of development of the market.

However, as fast charging technology matured and more supportive policy emerged, fast charging became more common and gained traction with ELVs without the ability to slow charge, as well as with other commercial EVs such as taxis. Concurrent unit cost reduction of charger deployment and increased charger utilization led to rapidly decreasing costs of fast charging per kWh.

These lower costs induced further electrification of commercial vehicles and again greater charger utilization leading to further investment in the fast-charging network. This process continues to play out and, according to our interviews, is creating demand for public chargers with power up to 100 kW. Such chargers would be able to fully charge a minivan in approximately 15–20 minutes and light trucks in less than an hour. This brings charge times much closer to ICE fueling times and greatly reduces charging-related ELV utilization penalties.

RECOMMENDATIONS

In light of this analysis, the research team has composed five recommendations for charging station planning.

Prioritize fast charging installation

Through data analysis and interviews, it is clear that there is a strong preference for logistics fast charging. New ELVs registered in Shenzhen are using increasing amounts of fast charging in their daily routines; the vast majority of growth in charging demand in 2019 was for fast charging. Furthermore, stakeholders quote the need to benchmark charging times against ICE vehicle refueling times in order to use ELVs in similar ways as diesel and gasoline vehicles. Shenzhen already has policies, such as charger subsidies and preferential electricity prices, which prefer DC fast charging. Ensuring that the supply of fast charging keeps up with the growing demand will provide logistics operators with the freedom to fully electrify their fleets.

Build charging stations in areas with high logistics density

Most ELV charging in Shenzhen occurs in Longgang, Longhua, and Baoan, districts of the city with high logistics enterprise density. Meanwhile policy has focused on public, fast-charging installation in the more populous districts of Futian, Nanshan, and Luohu. In order to support the electric logistics market, Shenzhen policy should focus public fast-charger installation on the industrial districts of Longgang, Longhua, and Baoan in order to provide more available charging near where these vehicles are known to charge.

Within districts, establish charging stations in proximity to known points of charging demand

Especially within Shenzhen, where some districts are sprawling, simply targeting charging station installations within the district is not enough to ensure that the stations will be used for logistics charging. In order to encourage public usage of charging stations, Shenzhen should target charging installations near areas with industrial parks, commercial regions, and logistics warehouses (freight origin, freight destination, and vehicle overnight parking points).

Build stations near overburdened public stations

A benefit of spatial data analysis to inform charging policy is the granularity with which recommendations can be made about macro-scale transportation dynamics. Through analysis of charging telematics data from logistics vehicles, it is possible to quantify the location and amount of logistics vehicles queueing around different charging stations in the city. Shenzhen should target charging installations in those locations where logistics vehicles experience the highest congestion waiting for charging availability. This queueing analysis, though not part of current RMI research, is something that the research team hopes to accomplish in the near future.

Shorten bureaucratic delays

One barrier to effective deployment of EV charging infrastructure frequently discussed in stakeholder interviews was wait times in gaining approvals for charger installation, often in excess of six months. This results in high soft costs, such as tied up working capital and administrative burdens created by those delays.

Three specific sources of delay were most frequently cited. First were approvals from Southern Grid for charger installation and the extended time needed to install new transformers for areas that were not able to meet the load anticipated from ELV charging. While Shenzhen's timeline for approving and installing new "make-ready" infrastructure is quite fast relative to other cities globally, it is not sufficiently fast to enable logistics electrification at the pace targeted by Shenzhen's policymakers.

The second source of delay is land use approvals carried out by Shenzhen's Department of Land Management. This process is necessary as it seeks to identify and eliminate any safety hazards from new construction, but again could be streamlined to keep ELV adoption on its targeted trajectory.

Finally, a third source of delay and often project failure is a refusal by land owners to allow charger installation on property leased by logistics firms. If a land owner agrees to the installation of chargers, typically there is no added time. However, landowners often demand extra lease payments or other forms of payment to allow for charging at those warehouses. The time spent negotiating those terms and the cost added to charging from those payments both represent a significant additional cost and result in depot charging costs that are higher than public DC fast charging on a kWh basis.

In order to overcome those delays, Shenzhen can research and implement models of collaboration between charge station providers and utilities to accelerate the deployment of "make-ready" infrastructure for charging. It can also streamline processes for land use applications and explore regulation of landowner ability to impede or delay charging infrastructure installation as a strategy for extracting monopoly rents from vehicle owners.

ENDNOTES

1. *Putting Electric Logistics Vehicles to Work in Shenzhen: Setting the Stage for Full Utilization of ELVs in Shenzhen,* Rocky Mountain Institute, 2020.
2. Factors to Consider before Purchasing Electric Logistics Vehicles, EV Resources, 2018, https://m.sohu.com/a/229401898_233844.
3. Revitalization and Development Plan for the New Energy Industry in Shenzhen, Shenzhen Municipal Government, 2010.
4. Guangdong Province New Energy Vehicles Statistics, Shenzhen Xieli Innovation Center of New Energy and Intelligent Connected Vehicles, 2020.
5. Shenzhen New Energy Vehicles Promotion and Application Actions, Shenzhen Municipal Government, 2015, http://www.fzb.sz.gov.cn/gfxwj/201710/t20171024_9407094.htm.
6. *Shenzhen 2016 New Energy Vehicles Promotion and Application Supporting Policies,* Shenzhen Financial Department, 2016, http://www.szpb.gov.cn/xxgk/qt/tzgg/201609/t20160905_4413330.htm.
7. Ibid.
8. Guangdong Province New Energy Vehicles Charging Electricity Rate Notice, Guangdong Development and Reform Commission, 2018, http://www.szpb.gov.cn/xxgk/qt/tzgg/201807/t20180705_13531111.htm?from=singlemessage&isappinstalled=0.
9. Shenzhen Vehicles Parking Fee Management Notice, Shenzhen Development and Reform Comission, 2017. http://www.szpb.gov.cn/xxgk/qt/tzgg/201712/t20171229_10633515.htm.
10. New Energy Vehicles Temporary Free Parking Notice, Shenzhen Municipal Government, 2018. http://www.sztb.gov.cn/hdjl/zjdc/zjfk/201804/t20180426_11794352.htm.

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