ENERGY FOUNDATION
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PUTTING ELECTRIC LOGISTICS VEHICLES TO WORK IN SHENZHEN

Summary Volume: Charting a Path to Fully Electrifying Goods and Logistics Delivery

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 office in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

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EVOA

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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EXECUTIVE SUMMARY

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Over the past five years, Shenzhen has rapidly developed its market for electric logistics vehicles (ELVs) and has emerged as a global leader in logistics electrification. Over the past three years, Rocky Mountain Institute (RMI) has worked with Shenzhen to better understand how logistics electrification has played out in the city and to suggest refinements to the approaches of the public and private sector to sustain and accelerate that process.

This paper is the final report in the *Putting Electric Logistics Vehicles to Work in Shenzhen,* series. It is a summary of the five previous reports on the utilization rate of electric logistics vehicles in Shenzhen as well as pathways to improvement. For a detailed look at different aspects of ELV utilization in Shenzhen please refer to the following reports:

- **Background Volume:** Setting the Stage for Full Utilization of ELVs in Shenzhen
- **Policy Volume:** Utilization Subsidies as a Lever to Accelerate the ELV Market
- **Infrastructure Volume:** Enabling EV Utilization through Well-Planned Charger Deployment
- **Vehicle Quality Volume:** Identifying Pain Points in ELV Performance that Reduce Utilization
- **Business Model Volume:** Improving Utilization of ELVs through Innovations in Business and Ownership Models

While the previous five volumes of this report focused on in-depth analysis of the ELV market in Shenzhen, this volume adopts a more global view. That is because the need for urban freight electrification is not unique to Shenzhen; it is rapidly becoming a priority across the world. This is due to its impact on both the climate and human health. Globally, light and medium freight vehicles account for nearly half of overall road freight CO_2 emissions,[1] and in 2015 an estimated 181,000 people around the world died from diseases caused by emissions from diesel vehicles.[2]

This problem is only set to get worse. With, the development of e-commerce, the role of commercial vehicles in getting goods to customers has been growing steadily over the last decade. This year, with the outbreak of the coronavirus, e-commerce purchases and deliveries have exploded, growing by approximately 50% in the first half of 2019 in the US.[3] For that reason we shift our focus in this document from an in-depth discussion of the status quo in Shenzhen, to framing the learnings from Shenzhen in a way that is relevant to cities globally.

From Europe to North America to Asia cities have taken the lead on electrification of urban logistics and are a crucial actor. The control of cities over policies affecting land use and air quality gives them unique levers to influence the relative cost of operating ELVs versus internal combustion engine (ICE) vehicles. However even more important is the ability to issue targeted policies based on cities' proximity to their citizens and businesses.

As those cities and states undertake the task of logistics electrification, we hope that our work with Shenzhen can inform their planning and smooth their path. To enable city and state action, we provide insights on Shenzhen's policy portfolio, trends in both infrastructure provision and use of infrastructure, and vehicle performance pain points, with a focus. on battery degradation. Finally, we look at the ownership and business models which have enabled rapid ELV deployment. **From this we distill several key messages for cities looking to electrify urban logistics. They are:**

- **Full logistics electrification is possible.** Shenzhen’s experience shows that a rapid transition to the use of EVs in urban logistics is feasible and, with the proper policy framework, vehicle operators will rapidly electrify.

- **Focus first on electrifying the simple use cases.** In the initial stages of ELV deployment, cities should focus on electrifying the relatively simple use cases that can help OEMs gain a reliable market and establish a track record of success. Cities can use those use cases first to foster a first wave of electrification that can prime the system for further success.

- **Policy must evolve as logistics electrification progresses.** As the low-hanging fruit of logistics electrification is picked, policymakers must be prepared to pivot toward harder use cases. Doing so will change how cities approach vehicle incentivization and infrastructure deployment. Being able to dynamically adjust policy to the needs of distinct market segments as they electrify is critical to success.

- **Policymakers must create the capabilities to understand and evaluate the ELV market.** For cities to continuously improve policy, they should both build the framework for stakeholder engagement with the logistics industry as well as build the data collection framework to understand how vehicles are operating. This combination has been powerful in Shenzhen.

- **Growing an ELV fleet is a necessary but insufficient condition for logistics electrification.** Policymakers often set EV targets in terms of share of sales or share of fleet. Getting EVs into the hands of operators is the first step in full logistics electrification but not the only step. Cities must also ensure that ELVs are able to displace the use of fossil fuel vehicles.

- **Coordination with other jurisdictions is necessary for a successful policy portfolio.** Logistics travel patterns cross over political jurisdictions routinely. For maximum effectiveness, cities should work with other political authorities to create a policy framework that has a metropolitan or regional scope.

- **Infrastructure is the key enabler of logistics electrification, but choices in infrastructure have far-reaching consequences.** A city must take an active role in ensuring the emergence of a robust charging system. However, as cities build out that network, they must consider the systemic effects it creates, continuously evaluate the results of decisions they make, and improve policymaking accordingly.

- **Encourage innovation and entrepreneurialism in the supporting ecosystem.** ELVs present the market with new challenges and opportunities and enabling the market to meet those challenges is key to the success of logistics electrification. Cities can support innovation in multiple ways, including engaging with industry to support innovative pilots that support proof-of-concept for new approaches to logistics electrification.

LOGISTICS ELECTRIFICATION IS EMERGING AS A PRIORITY IN CITIES GLOBALLY

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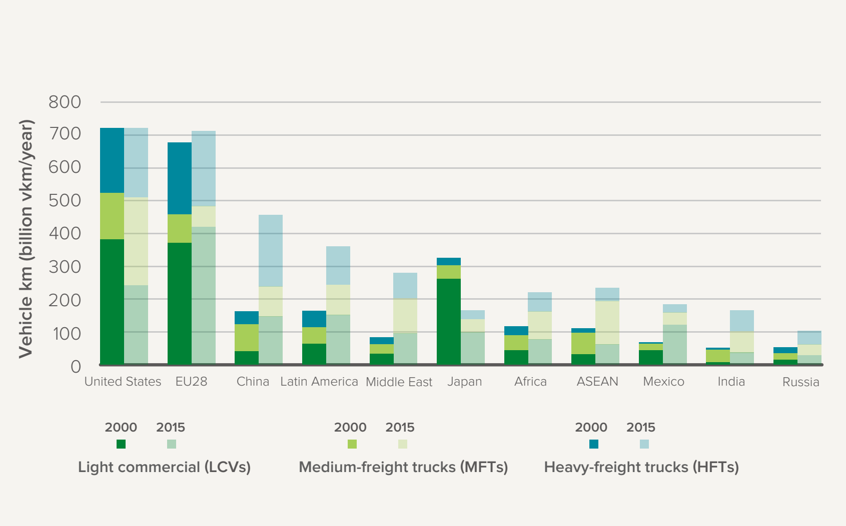
IMPORTANCE OF URBAN FREIGHT ELECTRIFICATION

Light- and medium-duty delivery vehicles form an integral part of supply chains and constitute a substantial share of commercial vehicle traffic, pollution, and CO_2 emissions globally. According to the International Energy Agency (IEA), light- and medium-duty freight vehicles accounted for approximately 70% of total freight vehicle kilometers (km) traveled in 2015. These vehicles drove a total of approximately 1 trillion km in the United States and the EU alone (see Exhibit 1).[4]

EXHIBIT 1

Freight Vehicle Use by Geography in 2000 and 2015
(billions of vehicle kilometers per year)



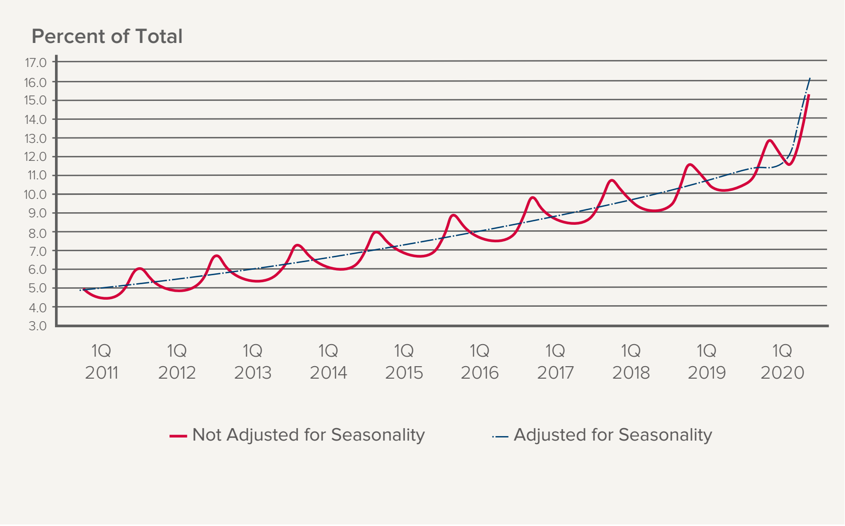
Source: IEA

These vehicles are also major sources of CO_2 emissions. Again, according to the IEA, light-and medium-duty freight vehicles accounted for nearly 50% of overall road freight CO_2 emissions and energy or approximately 1.5 Gt and 16 exajoules respectively in 2015.[5] Furthermore, freight, and especially urban freight, are major drivers of air pollution and associated disease. In 2015, approximately 181,000 people globally died due to diesel vehicle tailpipe emissions,[6] primarily due to freight vehicles operating in cities.

This problem is expected to intensify as e-commerce grows in popularity and the role of commercial vehicles in getting goods to people's homes grows. For example, between 2011 and the first quarter of 2020, e-commerce as a share of total US retail sales grew steadily, from approximately 5% to 11%. However, in the second quarter of 2020, with the global outbreak of the novel coronavirus, that share abruptly leaped to 16%. This accelerated a transition long in the making (Exhibit 2).[7] This growth in e-commerce and home delivery is putting more freight vehicles on city streets and raising the urgency for their electrification.

EXHIBIT 2

Estimated Quarterly US Retail E-commerce Sales as a Percent of Total Quarterly Retail Sales: 1st Quarter 2011–2nd Quarter 2020

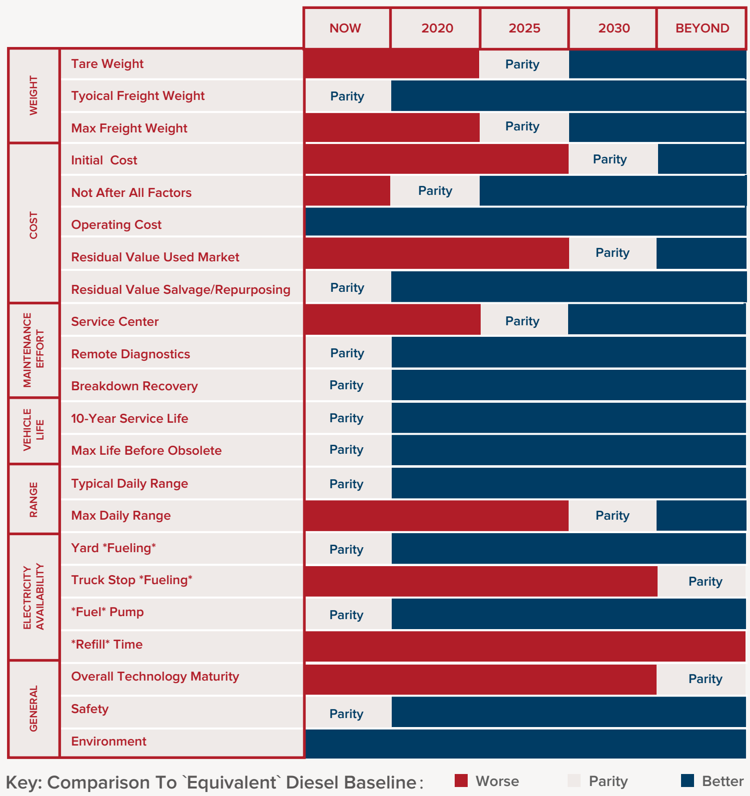


Source: U.S. Census Bureau

Fortunately, as the need to electrify final-mile urban delivery has intensified, electric logistic vehicles have increasingly become able to meet the challenge, both in terms of technical capabilities as well as cost-competitiveness with internal combustion engine ICE vehicles. For example, the North American Council on Freight Efficiency (NACFE) estimates that as of 2020, electric medium-duty vehicles typically used in urban logistics applications in the United States are able to compete with similar diesel vehicles on most evaluation metrics, including total cost of ownership (Exhibit 3).[8]

EXHIBIT 3

Class 3 Through 6 CBEV Parity vs. Diesel System (NACFE)

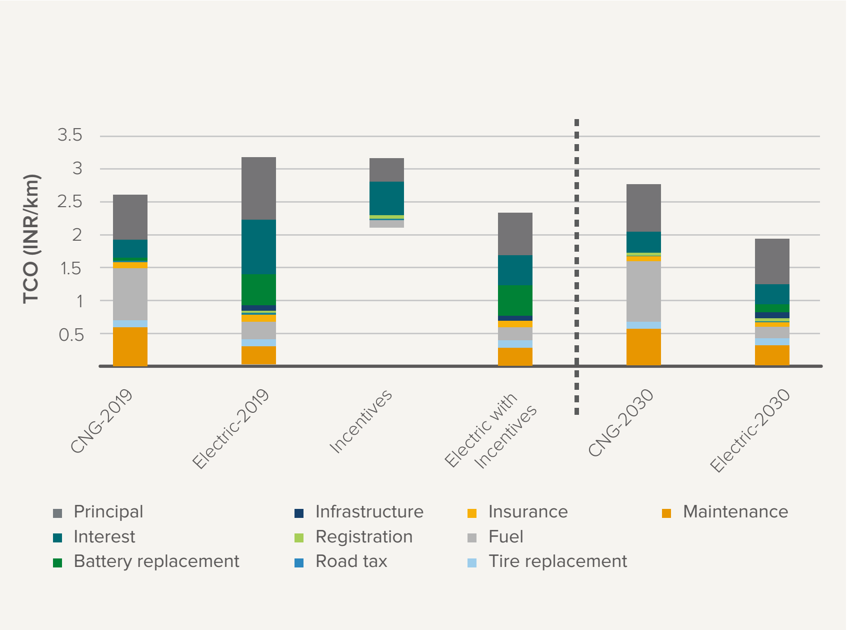


Source: NACFE

Similarly, in India the most commonly used urban logistics vehicles (three-wheeled delivery vehicles with a loading capacity of up to 750 kilograms) are also near total cost of ownership (TCO) parity with compressed natural gas (CNG) competitors without subsidization. This is notable because gas and diesel-powered three-wheelers are banned in Delhi for air quality reasons. Those ELVs vehicles are currently less expensive than CNG competitors with incentives that have been instituted in Delhi (Exhibit 4) and are expected to reach unsubsidized TCO parity in two years (Exhibit 5).[9]

EXHIBIT 4

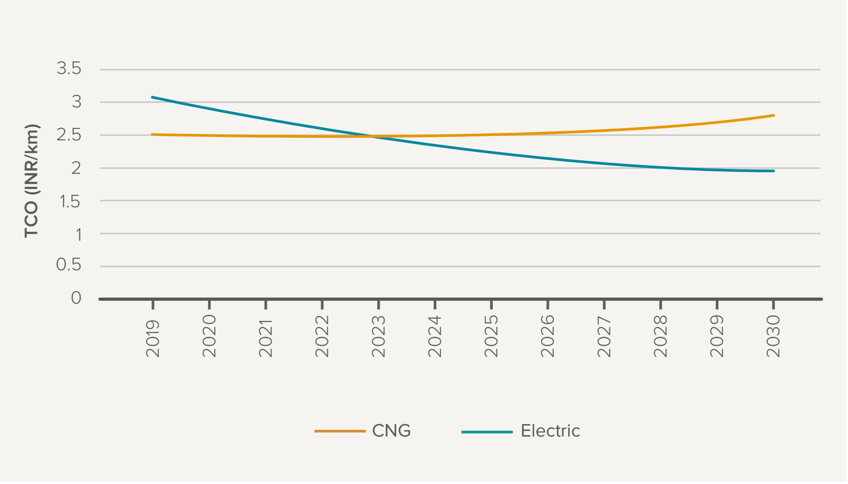
TCO Comparison Between Electric and CNG Three-Wheeler Goods Vehicles in Delhi



Source: Deliver Electric Delhi

EXHIBIT 5

Electric Three-Wheelers Will Be at Cost Parity with CNG Vehicles in Terms of TCO by 2022 in India (without subsidies)

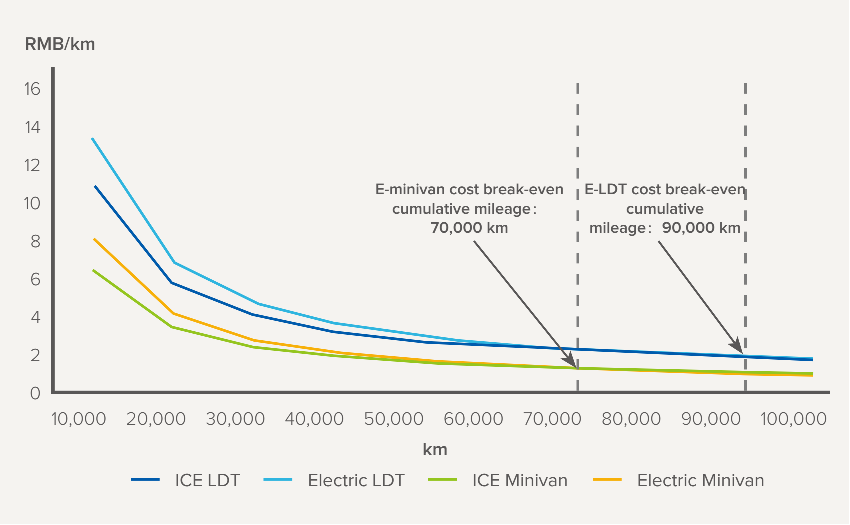


Source: Deliver Electric Delhi

Finally, in Shenzhen's current policy environment, both electrified minivans and light trucks currently are cost-competitive with ICE counterparts at annual utilization levels of 14,000-18,000 km. These levels are commonly achieved in urban logistics applications (Exhibit 6).

EXHIBIT 6

TCO Comparison Between ICE Vehicles and ELVs in Shenzhen



Source: RMI Analysis

As the value proposition of ELVs increasingly matures, and as the consequences of inaction on urban logistics electrification are increasingly apparent, cities, states, and countries globally are taking aggressive action to electrify urban logistics.

CITY, STATE, AND REGIONAL ACTION ON URBAN LOGISTICS ELECTRIFICATION GLOBALLY

As a global appreciation of the need for urban freight electrification grows, policymakers are rolling out actions to drive the purchase and use of electric logistics vehicles (ELVs). These actions come in a variety of forms such as pollution taxes, ultra-low emissions zones that ban ICE vehicles in certain areas of the cities, production requirements for zero-emissions freight vehicles, ZEV credit policies, and fiscal and non-fiscal support for ELVs. These electrification pushes cover the spectrum of freight vehicles, from medium and heavy vehicles which are the focus in the United States, to light vehicles such as scooters and three-wheelers in India.

Cities and subnational governmental bodies such as states and regions are crucial players in logistics electrification for several reasons. The first is land. Substantial land is needed for ELV charging and city governments are often major landowners and also write laws and codes that dictate land use.

The second is regulatory authority. Many cities can enact legislation to improve air quality through policies like low, ultra-low, and zero-emissions zones, or reduce congestion through entry restrictions and congestion pricing. These policy tools can be deployed to support EV adoption.

The third, and potentially most important, is the relationship that cities have with both business and citizens. This close connection enables cities to create nuanced, targeted policies that are in tune with the needs of the people they effect. In practice, while national governments have provided support for vehicle electrification through fiscal incentives, it is typically cities and states that are driving on-the-ground adoption.

In the United States, California has led the way. Driven by aggressive climate change targets and hazardous air pollution from diesel trucks operating in its cities (especially in low-income neighborhoods), California adopted the Advanced Clean Truck regulation, which requires original equipment manufacturers (OEMs) to produce and sell zero-emissions freight vehicles. Depending on vehicle class and chassis type, sales of electric medium- and heavy-duty trucks must represent between 40% and 75% of the total market in 2035.

While mandates are a key element of California's freight electrification program, they are also supported by incentives. Through its Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) program, California subsidizes both the up-front cost of heavy-duty electric vehicles as well as the infrastructure needed to charge them. Other states are following quickly. Fourteen states (California, Colorado, Connecticut, Hawaii, Maine, Maryland, Massachusetts, New Jersey, North Carolina, Oregon, Pennsylvania, Rhode Island, Vermont, and Washington) plus Washington, D.C., have signed a memorandum of understanding to follow California's pathway to full trucking electrification by 2050.

Europe has been even more aggressive than the United States in its push for freight electrification. For example, Amsterdam has barred ICE vehicles, including freight vehicles, from the inner city beginning in 2025. In 2030 Amsterdam will extend that coverage out from the city center to cover the entire city. Oslo has taken similar measures. Many other European cities in France, Italy, and the UK are not far behind with commitments to ban ICE vehicles, including logistics vehicles, over the coming decade.[10]

Finally, the push toward urban logistics electrification is not exclusive in wealthy cities and states in North America and Europe. In addition to Shenzhen, China, which has led logistics electrification over the past half decade, Delhi, India, has also rolled out supportive policies for ELVs. Specifically, it has subsidized the purchase of electric delivery vehicles as well as the scrapping of old ICE vehicles by the purchaser of an ELV. Additionally, it has exempted all ELVs from any bans on plying and idling that currently apply to ICE logistics vehicles operating in the city.[11]

INSIGHTS FROM SHENZHEN

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As cities globally take action to electrify urban logistics, the goals and timelines are clear: a consensus has emerged among first-mover cities to fully electrify logistics by 2030–2035. However, the pathway there is not known; the world has never seen a fully electrified urban logistics system. Each city will follow its own path to logistics electrification and have a different set of tools at its disposal.

Looking to Shenzhen, which is furthest along the pathway to full logistics electrification with an ELV fleet of more than 70,000 vehicles, may help make the journey for other cities smoother. In this series of reports, we have focused on four critical aspects of logistics electrification: policy, infrastructure, vehicle capabilities, and vehicle ownership models. Here we do not discuss in depth how Shenzhen is performing on each of those aspects, but rather the high-level takeaways from Shenzhen that other cities can utilize to inform their own electrification plans. An in-depth analysis is available in the individual reports.

POLICY

While unsubsidized ELVs are projected to achieve TCO parity with ICE competitors in the next several years, the market is not yet mature enough to succeed on its own. At this stage, urban logistics electrification still needs policy support. Cities have multiple options for how to provide such support and an effective policy portfolio must deploy all of those options:

- first is enhancing ELV cost competitiveness through subsidization of the vehicle,
- second is through reducing the value proposition of ICE vehicles through access restrictions such as low- or zero-emissions zones,
- third is accelerating charging infrastructure build-out through subsidization of capital cost, and
- fourth is through enhancing ELVs' existing operating cost advantages through preferential electricity rates or taxes on fossil fuels.

By changing the value proposition of ELVs' relative to ICE vehicles, and simultaneously ensuring that a suitable ELV charging infrastructure system emerges, cities can achieve rapid growth in ELV fleets. This will bring both reduced carbon emissions and cleaner air.

And while policymaking is an important element to ELV fleet growth, it cannot be static. A broad array of policies such as urban entry restrictions, vehicle subsidies, and fuel subsidies can create a complex incentive structure for logistics companies that respond by optimizing their vehicle use patterns in unexpected ways.

For example, in Shenzhen, policymakers were initially focused on growing the fleet, which they accomplished through generous purchase incentives combined with city entry restrictions. However, because those ELVs were very cheap and provided the option for easier access to the city center but were oftentimes not suitable for more challenging routes, they were used as supplements, rather than replacements for ICE vehicles.

This was particularly severe for light trucks, which typically operated outside of the city core and were less affected by entry restrictions than vans. As a result, Shenzhen was left with a large, but at times poorly utilized, ELV fleet. This was especially true for light-duty trucks. Policymakers had to understand the root causes of that poor utilization and adjust accordingly, which led them to reevaluate both how vehicles were being subsidized along with how charging infrastructure was being deployed.

In 2019, policymakers in Shenzhen were confronted with both the problem of low utilization as well as the winding down of the purchase subsidy framework that had driven ELV purchases earlier in the decade. Knowing that ELVs were not yet capable of competing with ICE vehicles on cost alone, but also knowing that purchase subsidies had not yielded sufficient return on the subsidy funds due to low vehicle utilization, Shenzhen introduced the operational subsidy.

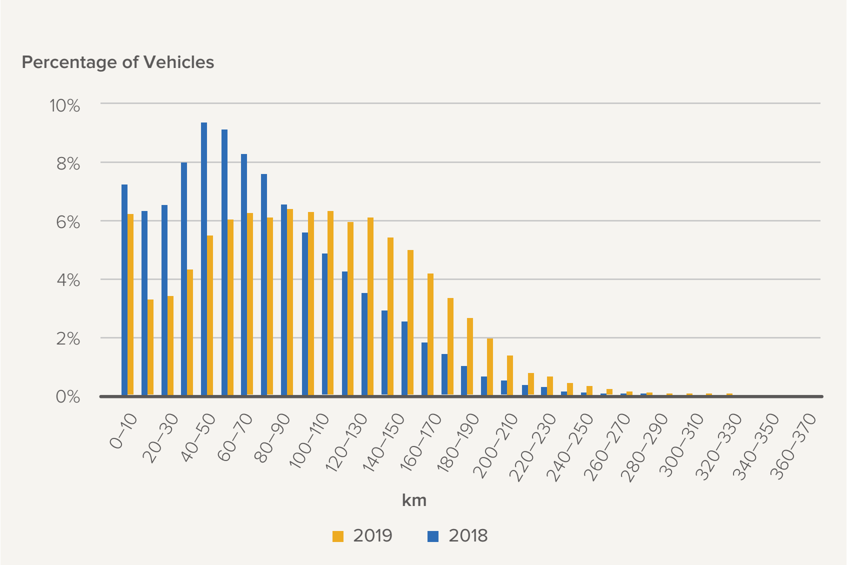
This subsidy was roughly equal to the discontinued purchase subsidy in terms of money available to an ELV purchaser. However, payments were divided into three installments and paid annually only to vehicle owners who had met the utilization threshold of 15,000 km driven per year. While this did not alter the overall per-mile cost of ELVs for qualified vehicles, it did alter the daily decision of what vehicle an operator chose for a given route to ensure that the vehicle qualified for the subsidy. This in turn made it less likely that ELVs play a supplementary role to ICE vehicles in daily dispatch.

At the same time, Shenzhen began to research and implement charging infrastructure planning approaches that would support ELV use, rather than assuming that all logistics vehicles would be able to charge at night at the depot. By focusing on making fast charging available to logistics users, especially owner operators and small businesses that did not have reliable access to a self-owned parking spot in which they could install a charger, Shenzhen was able to expand ELV use into new market segments.

As a result of this shift in policy portfolio, utilization rates of ELVs in Shenzhen improved markedly in 2019 (Exhibit 7), which reduced CO_2 emissions by 27,000 tons and particulate matter by 1.2 tons compared with 2018.

EXHIBIT 7

Average Daily Driving Distances in Kilometers of ELVs in Shenzhen



INFRASTRUCTURE

In tandem with its investment in a very large fleet of electric vehicles for both freight and passenger applications, Shenzhen also invested heavily in the charging infrastructure necessary to effectively provide those vehicles with energy. Those investments came primarily in the form of financial incentives to the construction and use of charging infrastructure.

The key elements of that policy package were up-front subsidies to install infrastructure, preferential electricity rates including access to industrial tariffs, and exemption from demand charges for large-scale charging stations. Regulated services fees collectible by charging station operators that capped electricity prices to vehicles were also important. Collectively, this policy portfolio invested substantial government capital into charging infrastructure build-out and ensured low priced electricity was available to vehicles. It did this while enabling adequate, but not monopolistic, returns to private-sector companies that installed the infrastructure.

This policy, along with burgeoning demand from the rapidly growing EV fleet in Shenzhen, led to rapid growth in charging infrastructure in Shenzhen. However, that growth was not without problems. In the initial stages of infrastructure build-out, many small companies competed to build up charging networks, leading to a highly fragmented charging network that was often unreliable and unevenly maintained. As a response to this, Shenzhen restricted incentives only to companies that were able to invest in charging infrastructure at significant scale. This ultimately led to a network in which vehicle users expressed high levels of confidence and satisfaction.

Furthermore, initial rounds of infrastructure deployment were not always in line with the needs of vehicles, especially logistics vehicles, both in terms of location as well as type of chargers. In the early stages of infrastructure deployment in Shenzhen, the assumption from the city was that logistics vehicles would be charged at the depot, overnight, through slow charging with a capacity of 3–7 kilowatts. This assumption held true for early deployments by large fleets with predictable routes and land to install chargers. Most charging events occurring at logistics facilities were vehicles that plugged into slow chargers after a day's work (Exhibits 8 and 9).

EXHIBIT 8

Count of Charging Events at Logistics Facilities by Charger Power in Shenzhen

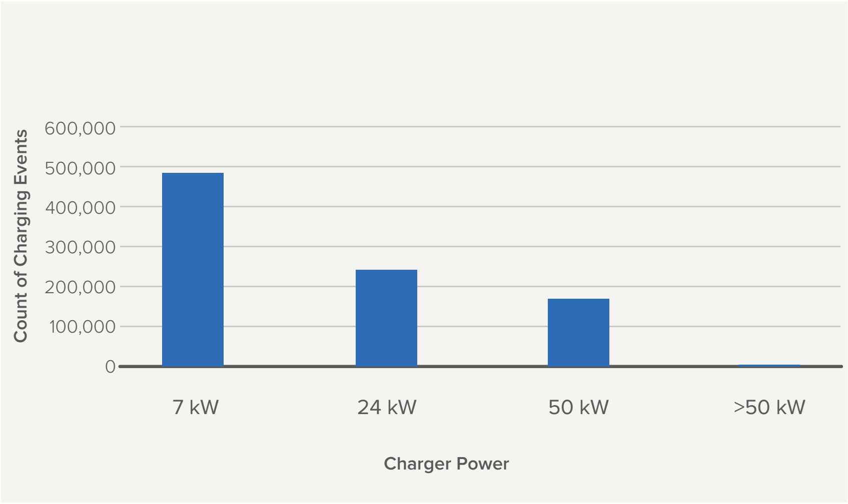
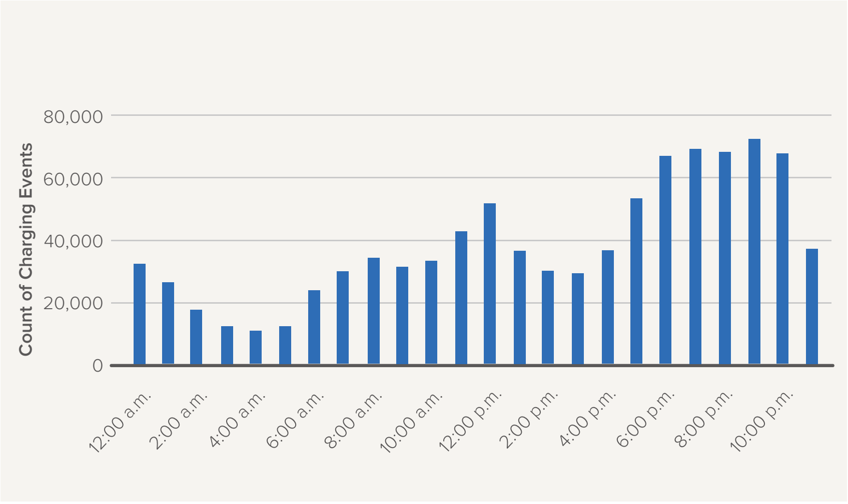


EXHIBIT 9

Count of Plug-ins by Hour at Logistics Facilities in Shenzhen



However, as the market grew, this assumption quickly became obsolete. Small-scale players with flexible routes and no land to install chargers began to purchase and use ELVs. And as fleets increasingly relied on ELVs as core generators of value, they began to benchmark their charging times against fueling times of ICE vehicles. This led to massive demand for fast charging in the ELV market. Between 2018 and 2019 almost every new vehicle that reported data to China's National EV Data Platform, which is the source of all EV data in these reports, exclusively used fast charging (Exhibits 10 and 11).

EXHIBIT 10

Share of Fast Charging by Vehicle (2018)

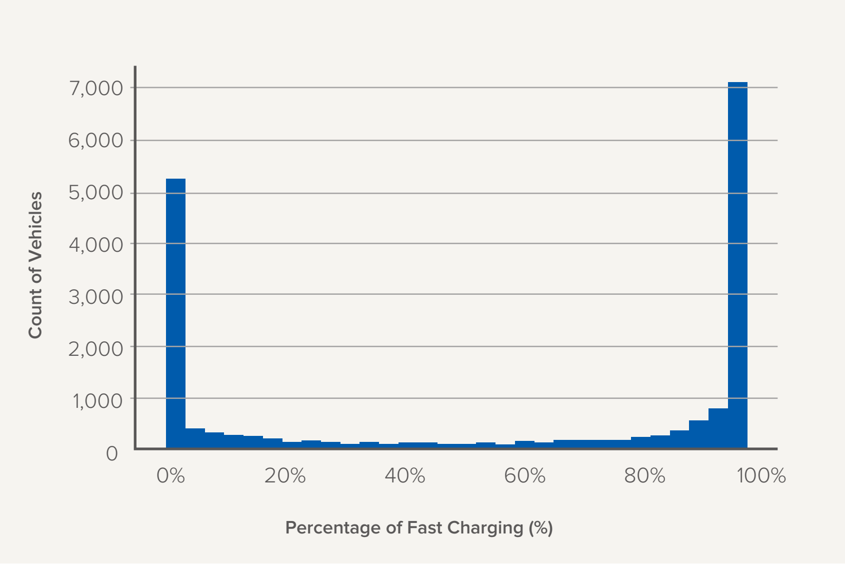
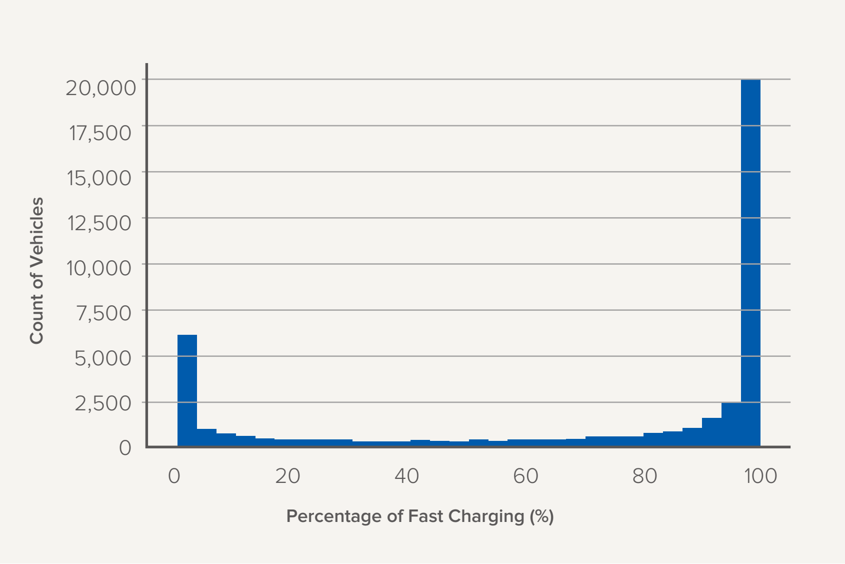


EXHIBIT 11

Share of Fast Charging by Vehicle (2019)



The result was a pattern of charging demand that was not originally contemplated by policymakers: heavy use of public fast charging by logistics vehicles. Far different from expectations, in 2019 nearly half of all energy used to charge ELVs was from public charging stations (Exhibit 13) and nearly 70% of energy dispensed to vehicles was from public and private fast charging.

EXHIBIT 12

Share of kWh Dispensed to ELVs through Fast and Slow Charging in Shenzhen

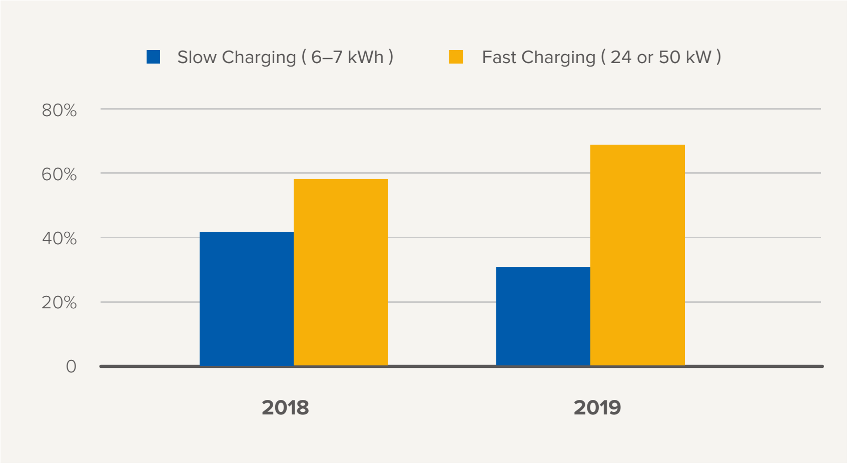
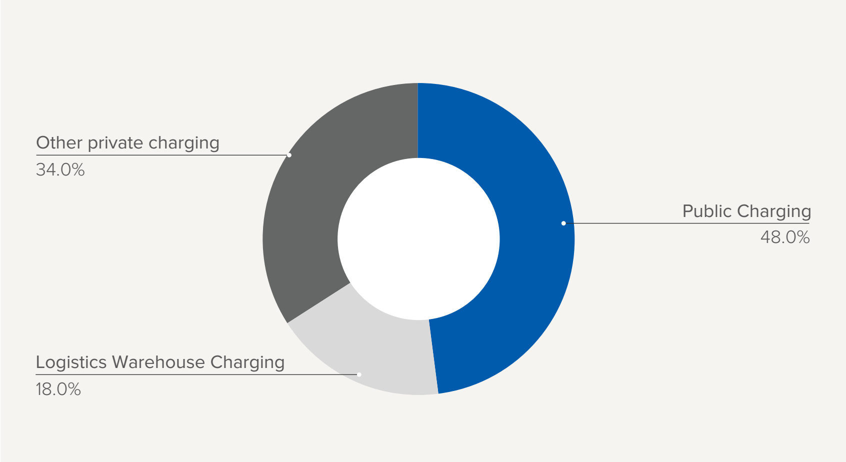


EXHIBIT 13

Proportion of kWh Charged at Each Location in Shenzhen

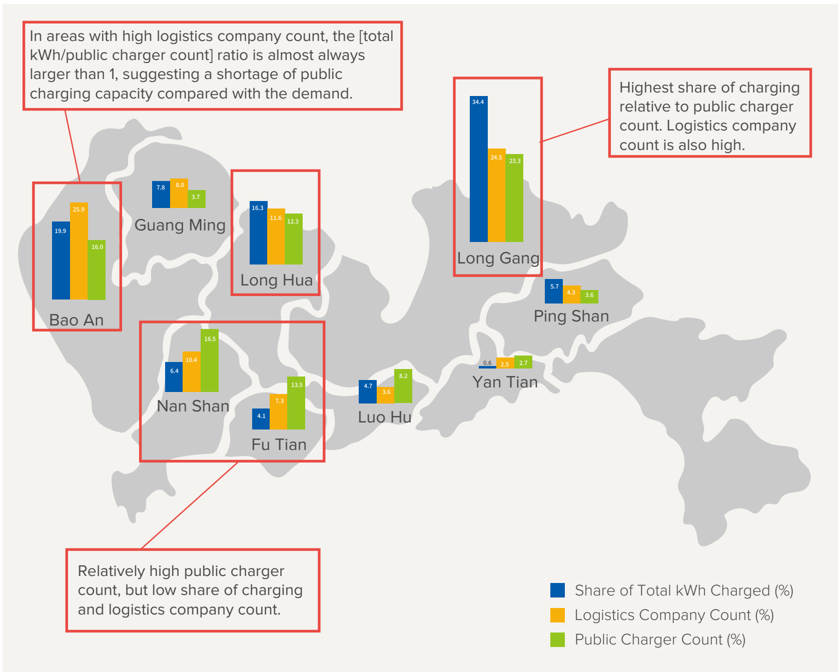


As a result of this preference for fast charging among ELVs (and other commercial vehicles), Shenzhen shifted its approach. First it implicitly included ELVs in public infrastructure planning and strove to resolve existing imbalances between the distribution of public charging and the distribution of charging demand from logistics users (Exhibit 14).

LOGISTICS ELECTRIFICATION IS EMERGING AS A PRIORITY IN CITIES GLOBALLY

EXHIBIT 14

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



Second, it focused on the installation of very large charging hubs capable of serving dozens or even hundreds of vehicles at once over smaller stations. The reason for this preference for large stations was economies of scale and utilization. Land acquisition for charging stations; utility investment in wires, cabling, trenching, and transformers; safety permitting; and maintenance are all cheaper on a unit basis when they are done at large scale rather than on a more dispersed system. Furthermore, large stations are better able to attract large numbers of customers and are more evenly utilized than smaller stations.

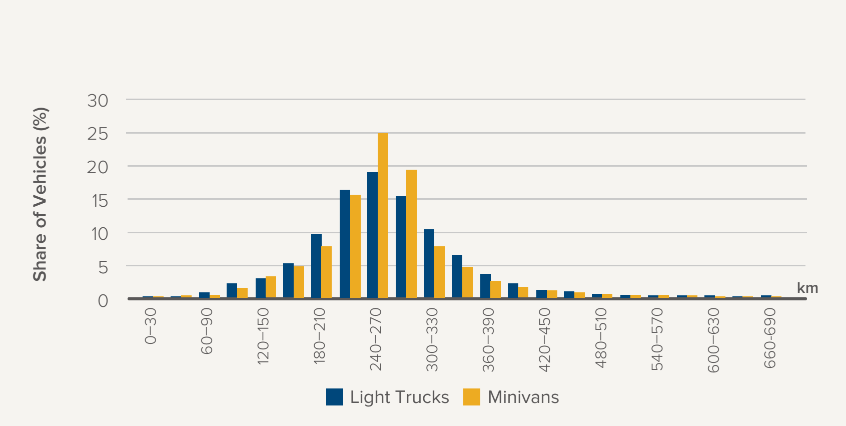
VEHICLE CAPABILITIES AND QUALITY

Infrastructure deployment, combined with the new operational subsidy, has driven vehicle utilization. Meanwhile, vehicle capabilities as a constraint on further electrification of urban logistics in Shenzhen have become an increasing area of focus. Specifically, with ELVs now widely expected to fully replace ICE vehicles in urban logistics in Shenzhen, users are demanding ICE-like performance from their ELVs. This has caused Shenzhen headaches in two major areas.

The first is ELVs' ability to effectively perform in demanding conditions such as on long distance routes, hauling heavy, dense freight, or hauling specialized freight like refrigerated goods. While heavy, dense freight and refrigerated goods transport are areas where operators have expressed significant concerns about ELVs, those types of freight are a relatively small share of overall deliveries.

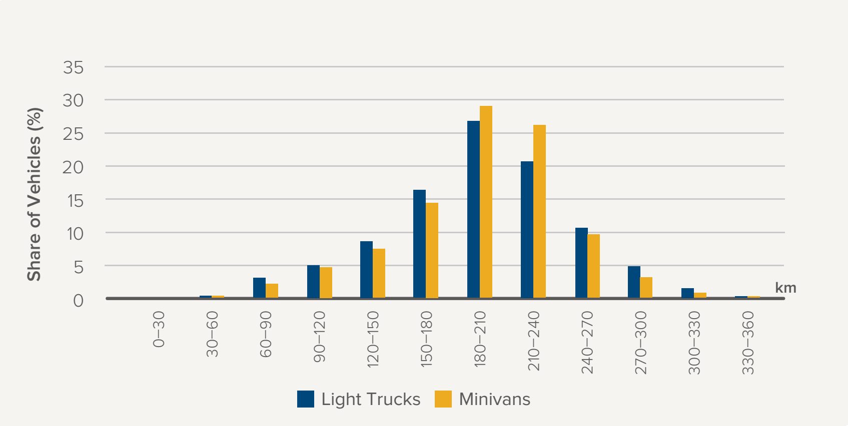
However, concerns over vehicle range are significant. Specifically, the difference in advertised range, mean achieved range, and worst-case scenario range has significantly reduced operator confidence in the ability of ELVs to reliably displace ICE vehicles. For ELVs in Shenzhen, advertised ranges are typically representative of best-case scenario operation, which is more or less normally distributed around a mean of 250 km (Exhibit 15).

EXHIBIT 15
Distribution of the Best-Case Scenario Estimated Range of ELVs on a Single Charge in Shenzhen



Not unexpectedly, this is about 20% greater than mean achieved range, which is approximately normally distributed around 200 km (Exhibit 16).

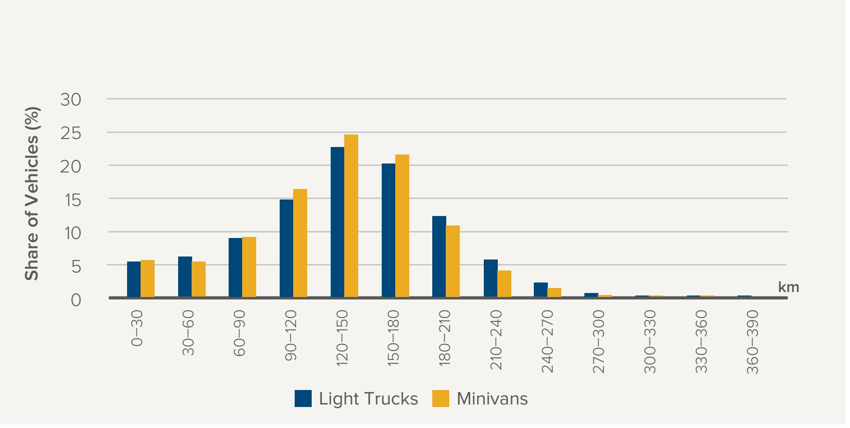
EXHIBIT 16
Distribution of the Estimated Mean Range of ELVs on a Single Charge in Shenzhen



However, worst case range is substantially worse and is distributed around 135 km (Exhibit 17) with a significant skew to the left.

EXHIBIT 17

Distribution of the Worst-Case Scenario Estimated Range of ELVs on a Single Charge in Shenzhen



This relatively high variability between advertised range, average expected range, and worst-case scenario range leaves operators reluctant to fully abandon ICE vehicles. Furthermore, as operators hold ICE vehicles in reserve for routes that ELVs may not be able to reliably complete, they also hold the option to opportunistically use them, creating a barrier to full replacement of ICE vehicles by ELVs.

The second vehicle performance concern is in vehicle useful life and battery degradation. As both Shenzhen policy and fleets push for high vehicle utilization, fast charging is increasingly becoming the norm. This has increased the flexibility and uptime of ELVs, and the widespread availability of public fast charging has increased operator confidence in the vehicles. However, it has also led to an unacceptably rapid loss of vehicle range for both minivans and light trucks (Exhibits 18 and 19).

EXHIBIT 18

Trend of Estimated Battery Degradation of Electric Minivans in Shenzhen

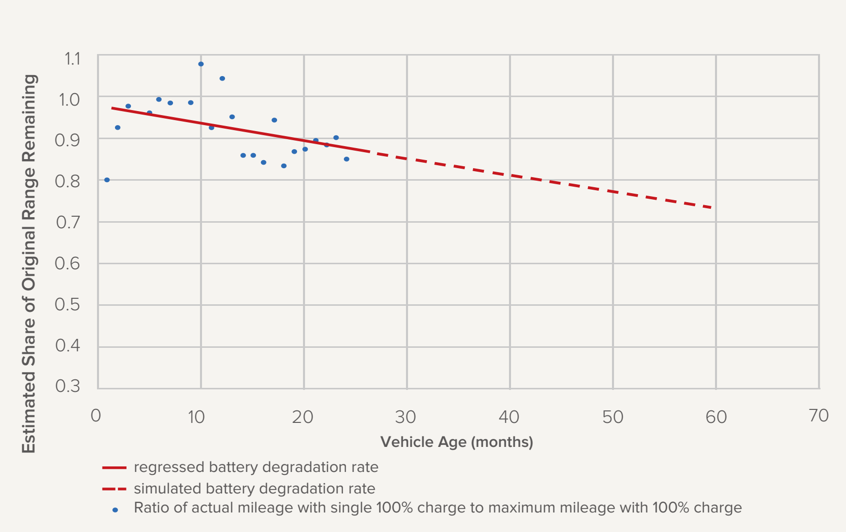
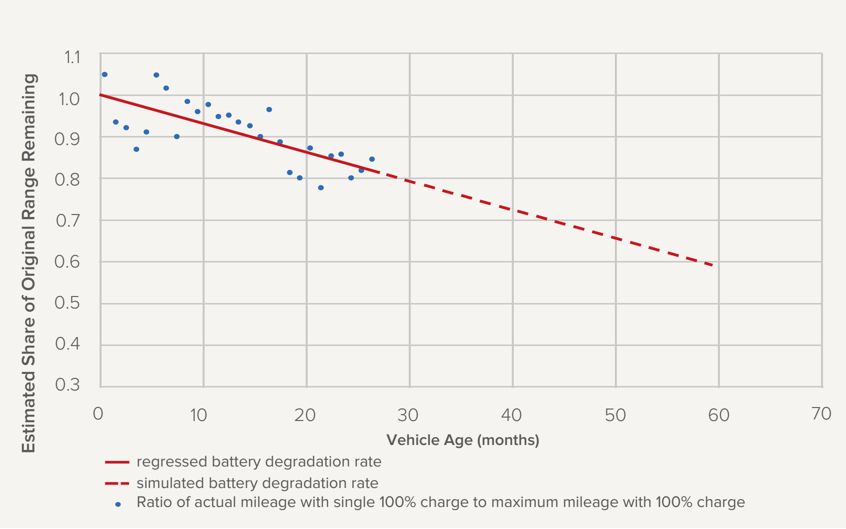


EXHIBIT 19

Trend of Estimated Battery Degradation of Electric Light Trucks in Shenzhen



This relatively fast battery degradation, and the resultant difficulty selling vehicles into the second-hand market, was the most cited quality and performance issue with ELVs in our research. For ELVs in Shenzhen to fully replace ICE vehicles in urban delivery, the issue of range and its degradation over the life of a vehicle must be resolved.

Furthermore, fleets typically purchase vehicles that can serve in all conditions, not only favorable ones. As other cities grow their fleets, keeping in mind how ELVs can meet not only the relatively easy demands of vehicle operators but also the more difficult ones will be important for scaled adoption. Cities must also consider what role policy and infrastructure can play in enhancing vehicle reliability.

OWNERSHIP MODELS

A notable feature of the ELV market in Shenzhen is the prevalence of leasing rather than vehicle ownership, which is how more than 95% of ELVs are acquired by operators. Short-term leasing models, with contracts as short as one month, have been critical for enabling operators to adopt ELVs with confidence.

There are three major reasons that operators choose to lease, rather than to purchase, ELVs. The first is the lack of a strong supporting ecosystem of maintenance and refueling for ELVs. Individual vehicle operators cannot build up maintenance and charging systems themselves, but leasing companies, which own thousands of vehicles, can. Once leasing companies establish these systems, they can provide them to customers as an overall package when leasing the vehicle.

The second is the cost structure of vehicles. Vehicle operators often have little or no access to credit. However, leasing companies often have strong balance sheets and are able to finance the high up-front cost of vehicles at relatively low rates. They also have the ability to maximize vehicle utilization, taking advantage of the low operating cost advantages of ELVs.

The third is policy preference for large-scale vehicle owners. In this section we focus on the first two factors as the third is idiosyncratic to Shenzhen.

The maturity and sophistication of the ecosystem that supports ICE vehicles is often underappreciated. Crude oil is pumped from the ground at massive industrial scales, a robust network of pipelines moves crude to refineries and, after refining, useful fuels run along mature supply chains to a highly developed distribution network.

Furthermore, ICE OEMs are among the world's largest most sophisticated companies. They maintain robust service and maintenance functions and have highly optimized supply chains to rapidly provide spare parts needed for vehicle repairs. Whereas for ELVs the electricity distribution network often requires substantial upgrades to accommodate charging, and chargers themselves must be installed.

Additionally, many EV OEMs are startups with immature supply chains for vehicles and parts and there is limited expertise in the specialized maintenance needs of ELVs. This lack of a robust existing ecosystem to support the operation and maintenance of ELVs makes operators reluctant to make a long-term commitment to vehicle ownership and instead lease vehicles.

Leasing ELVs also makes sense due to their high up-front cost and low operating costs. Most logistics firms, especially small and medium enterprises (SMEs), typically have poor access to capital and their borrowing costs to purchase vehicles are high. This can lead them to favor vehicles with a low up-front cost and high operating costs.

Leasing companies, on the other hand, are often much larger and have access to much cheaper financing than SMEs. At the same time, low operating costs reward vehicle owners who are able to maximize utilization of vehicles. While any given vehicle operator is exposed to seasonality and random fluctuations in demand, leasing companies can dynamically move vehicles among customers to smooth out those fluctuations over a diversified client base to obtain strong utilization of the entire fleet.

While the preference for leasing ELVs in the growth stage of the market in Shenzhen has been extremely strong, it should not be taken for granted that such dominance will persist indefinitely. Leasing does add a layer of cost and intermediation, and the supporting ecosystem for ELVs will grow out as they become the main vehicle for urban delivery. This suggests that in certain circumstances owners, especially large firms with low financing costs and predictable use patterns, may elect to own ELVs rather than lease them.

Indeed, in the relatively small instances where ELVs are not leased in Shenzhen, it is typically large-scale e-commerce firms that use them for the most predictable elements of their delivery activities. These firms still lease ELVs for the less predictable and more seasonal elements of their business. With this in mind, there is a possibility that leasing may lose some market share in the future. However, given the cost dynamics, leasing ELVs is likely to remain more common than leasing ICE vehicles.

While contractual arrangements for the ownership and use of a vehicle are best left to the private sector to navigate, cities can play a role in facilitating the emergence of such models. First and foremost, cities can look at existing policy portfolios and ensure that regulation is not unintentionally inhibiting the emergence of ownership models that are supportive of ELV adoption. Beyond this passive role of doing no harm, cities can also play an active role. Through their economic development agencies, cities can proactively engage with providers of innovative ELV ownership models to attract them to the city and facilitate their working with local delivery businesses and logistics firms.

A SYSTEMS VIEW OF POLICY, INFRASTRUCTURE, VEHICLE PERFORMANCE, AND OWNERSHIP

Policy, infrastructure, vehicle performance, and ownership are not independent. In fact, those four worlds all collide in the costliest component of an ELV: its battery. As mentioned above, the greatest source of ELV failure is battery degradation, and one of the main reasons that the leasing model has come to dominate in Shenzhen is the cost of the battery pack and fear that rapid degradation of the battery will render an expensive purchase useless in a short amount of time.

However, the main reason for battery degradation is a quest for high utilization enabled by fast charging. Both the emergence of fast charging and the quest for utilization in Shenzhen were the result of rational choices by vehicle owners, but ones made in a specific policy context that provided ample fast charging and explicitly rewarded high utilization.

Both the operational subsidy and the massive deployment of fast chargers were policy moves that supported the emergence of the ELV market as it exists today in Shenzhen. The massive deployment of fast charging was in response to moves by policymakers and Southern Grid. These parties sought economies of scale in grid upgrades and land use by creating large public fast-charging stations that were able to cater to multiple market segments such as logistics vehicles, taxis, rideshare vehicles, and private passenger vehicles.

At the same time, the operational subsidy reinforced the existing economic incentives to maximize utilization and vehicle uptime, further shifting the market to now widely available fast charging. To manage the risk of damage to batteries caused by fast charging, users now elect to lease, not own, their vehicles.

However, how to deal with a large stock of ELVs with highly degraded batteries for which no second-hand market exists remains a looming issue for Shenzhen. The pathway to resolving this issue is likely to be a two-pronged strategy that focuses on enabling second-life battery business models, such as stationary storage, while rapidly developing battery chemistries and charge management systems that can handle[1] a decade of fast charging.

As cities seek to chart their own pathways to full logistics and transport electrification, they can benefit from Shenzhen's experience. Specifically, they can evaluate the systemic effects of policy and infrastructure choices and ensure that both the technical attributes of EVs they deploy as well as the business and ownership models for those EVs are suitable to the policy and infrastructure decisions they make.

TAKEAWAYS FOR CITIES GLOBALLY

TAKEAWAYS FOR CITIES GLOBALLY

Each city has its own individual circumstances and each city's policymakers have different toolboxes that they can use to drive logistics electrification. Therefore, it is not reasonable to expect any city to follow Shenzhen's exact path. That path was a product of what the city needed and what city policymakers had the authority to do. However, there are several high-level takeaways that can be useful to all cities.

- **Full logistics electrification is possible.** Shenzhen has demonstrated conclusively that, when policymakers are motivated and create the right framework, logistics enterprises will electrify. Furthermore, that growth need not be gradual. A rapid transition to ELVs is feasible and exponential growth in the fleet, with annual growth rates in the high double digits, is possible. Cities should feel comfortable with setting aggressive targets for logistics electrification, knowing that, with proper policy support, industry can meet those goals.

- **Focus first on electrifying the simple use cases.** There is low-hanging fruit in logistics electrification, namely vehicles which run relatively long, predictable routes and spend the night at a fixed domicile with parking that is fully controlled by a large-scale vehicle operator. In the initial stages of ELV deployment, cities should focus on electrifying those relatively simple use cases. That can help OEMs gain a reliable market and establish a track record of success for ELVs in urban logistics. A mix of "carrots" in the form of vehicle subsidization, favorable electricity tariffs, and charging infrastructure subsidization, and a "stick" such as urban entry restrictions has been shown to be effective for spurring action in these types of applications.

- **Policy must evolve as logistics electrification progresses.** The low-hanging fruit of logistics electrification is quickly exhausted, and policymakers must shift to more complex use cases. Logistics is a notoriously fragmented industry, with small-scale operators dominating the market. These operators often have poor access to capital, do not own parking spots to install charging, and require high amounts of flexibility from their vehicles. Electrifying these market segments requires a different approach from policymakers, especially as it relates to infrastructure provision.

- **Policymakers must create the capabilities to understand and evaluate the ELV market.** ELV policies produce a complex set of incentives for vehicle operators. As operators optimize around those incentives, the results are often unexpected. For example, in Shenzhen, both the low utilization of ELVs before 2019 and the ongoing rapid battery degradation in ELVs were unexpected results of policy decisions that subsidized vehicle purchase and aggregated DC fast charging deployment. For cities to continuously improve policy, they should both build the framework for stakeholder engagement with the logistics industry as well as build the data collection framework to understand how vehicles are operating. This combination has been powerful in Shenzhen.

- **Growing an ELV fleet is a necessary but insufficient condition for logistics electrification.** Policymakers must also ensure that ELVs are replacing the kilometers driven by ICE vehicles. Many cities do not currently have the policy toolbox to drive utilization and there is no consensus on a path to do so. Shenzhen is experimenting with operational subsidies, but that may not be feasible in all cities. As cities seek to advance logistics electrification, they should develop the capabilities to understand and support not only vehicle sales, but also utilization, which ultimately delivers the social return on subsidy funds.

- **Coordination with other jurisdictions is necessary for a successful policy portfolio.** While municipal policymakers have authority over the core of a city, many aspects of logistics activity are often metropolitan or regional in nature. For example, urban access restrictions are effective for vehicles that have to enter the urban core, but not effective for vehicles that operate in the metropolitan area without entering the city itself. Coordinating with other jurisdictions on policy design can ensure that a fair, transparent, and effective policy framework exists for all vehicles and operators.

- **Infrastructure is the key enabler of logistics electrification, but choices in infrastructure have far-reaching consequences.** A city must take an active role in ensuring the emergence of a robust charging system. It is very risky to assume that a charging network for ELVs will emerge in a relevant timeframe based only on market incentives. However, as cities build out that network, they must consider the systemic effects it creates. The tradeoffs between economies of scale in infrastructure deployment, grid integration and load management, battery degradation, and utilization are consequential. The right balance between those tradeoffs is not yet known and cities should continuously evaluate the results of decisions they make and improve policymaking accordingly.

- **Encourage innovation and entrepreneurialism in the supporting ecosystem.** ELVs present the market with new challenges and opportunities. Enabling the market to meet those challenges is key to the success of logistics electrification. One innovation in Shenzhen was the rapid emergence of sophisticated ELV leasing companies and such ownership models are also likely to be important for other cities, especially as SMEs begin to use ELVs.

However, the need for innovation does not end with ownership models. As Shenzhen's approach shows, other innovation is still needed. For example, Shenzhen is now confronted with the question of how to provide suitable infrastructure for ELV charging while maximizing battery life and how to transition degraded batteries that are no longer suited to logistics use into other second-life applications.

Cities can support innovation in multiple ways. For example, they can design flexible, pathway-agnostic regulations in consultation with industry to ensure that policies are flexible enough to support an array of approaches to vehicle electrification. Cities can also engage with industry to support innovative pilots that support proof-of-concept for new approaches to logistics electrification.

ENDNOTES

ENDNOTES

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