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Electrifying on-road freight: Market review and policy suggestions for Guangdong province

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Introduction

Guangdong province in China recently made advancements to both mitigate climate change and improve air quality. These include reducing carbon emissions by a reported 22.35% from 2015 to 2020 and achieving an annual average fine particulate matter ($PM_{2.5}$) concentration of 20 µg/m³ in 2022.[1] The provincial government showed even greater ambition on July 25, 2022, when it announced the Implementation Plan on Carbon Peaking and Carbon Neutrality, which contains targets for achieving carbon peaking before 2030 and carbon neutrality by 2060.[2] The Action Plan on Air Quality Improvement (2021–2025) proposed by the Guangdong Department of Ecology and Environment will also set up targets to control of pollutants including $PM_{2.5}$, nitrogen oxides (NO_x), and volatile organic compounds.[3]

For years, Guangdong has been one of China's leading markets for new energy vehicles (NEVs), especially zero-emission vehicles (ZEVs).[4] Guangdong also recognizes the

1 Guangdong People's Political Consultative Conference, "Guangdong People's Political Consultative Conference Investigation Report," December 30, 2021, http://finance.sina.com.cn/jjxw/2021-12-30/doc-ikyakumx7286641.shtml; Department of Ecology and Environment of Guangdong Province, "Guangdong Air and Water Quality Report," February 3, 2023, http://gdee.gd.gov.cn/zlpm/content/post_4089450.html.

2 People's Government of Guangdong Province, "Implementation Plan on Carbon Peaking and Carbon Neutrality for Guangdong," July 25, 2022, http://www.gd.gov.cn/zwgk/zcjd/snzcsd/content/post_3980099.html.

3 Department of Ecology and Environment of Guangdong Province, "Action Plan on Air Quality Improvement (2021-2025)," 2021, http://gdee.gd.gov.cn/hdjlpt/yjzj/api/attachments/view/3a678053e4acfc685220f157a24809ce.

4 ZEV refers to battery electric vehicles and fuel-cell electric vehicles. NEV refers to ZEV and hybrid electric vehicles. Yidan Chu, Hui He, Lingzhi Jin, Xiyuan Wang, Jian Zhang, Fengfu Hao, and Yongwei Zhang, "Assessment of Leading New Energy Vehicle City Markets in China and Policy Lessons," (Washington, D.C.: ICCT, 2022), https://theicct.org/publication/china-city-markets-new-energy-sep22/.

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electrification of the transportation sector as one of the key tasks to support the dual targets of decarbonization and air quality improvement in the province's 14th Five-Year Plan.[5] Guangdong set an NEV sales target of 20% for 2025, and infrastructure development targets of 4,500 charging stations and 250,000 chargers.

The electrification of heavy-duty trucks (HDTs) is critical for achieving decarbonization goals. A study by the International Council on Clean Transportation (ICCT) showed that a 40% share for zero-emission trucks (ZETs) in new sales nationally in China in 2035 could reduce total carbon emissions from on-road vehicles by 25%.[6] Another study found that HDTs in Guangdong contribute about 30% of total carbon emissions from on-road vehicles even though these vehicles are only 2.5% of on-road stock.[7]

Currently, there are clear targets for the electrification of buses set at both the national level and by Guangdong province; electric bus sales are increasing quickly. Meanwhile, in 2021, the number of ZETs sold in China was only a third of the number of zero-emission buses sold that year. This is mainly because city buses typically drive fewer than 200 km per day on predictable routes; current electric bus technology can fully support those operations. In contrast, trucks often work with heavy loads and at long-haul ranges that current battery technology does not readily support.[8]

To understand the current opportunities and challenges for promoting ZETs in Guangdong province, this study reviews the local incentive policies and analyzes province- and city-level ZET sales and market penetration according to different technical perspectives. We then analyze the 5-year total cost of ownership (TCO) of dump trucks used to transport construction materials and waste, as this is the major use case for dump trucks in Guangdong. Lastly, we propose an incentive policy scheme to accelerate TCO parity for ZETs and promote ZET market development in Guangzhou and Foshan, two key cities in Guangdong province.

ZET market development and incentive policies

Provincial-level sales and incentives

Guangdong province has been the top ZET market in China in recent years. As shown in Figure 1, from 2019 to 2022, 26,293 battery electric trucks (BETs) and 1,498 fuel cell electric trucks (FCETs) were sold in Guangdong. Together, these accounted for 7% of all new trucks sold in the province over those years.[9]

5 People's Government of Guangdong Province, "Guangdong 5-Year Plan of Economic and Social Development and 2035 Targets," April 25, 2021, http://www.gd.gov.cn/zwgk/wjk/qbwj/yf/content/post_3268751.html; People's Government of Guangdong Province, "Guangdong 5-Year Plan of Comprehensive Transportation System," September 30, 2021, http://www.gd.gov.cn/zwgk/zcjd/mtjd/content/post_3555671.html; People's Government of Guangdong Province, "Guangdong 5-Year Plan of Ecological Civilization Construction," October 29, 2021, http://www.gd.gov.cn/zwgk/zcjd/bmjd/content/post_3595182.html.

6 Lingzhi Jin, Zhenying Shao, Xiaoli Mao, Joshua Miller, Hui He, and Aaron Isenstadt, "Opportunities and Pathways to Decarbonize China's Transportation Sector during the Fourteenth Five-Year Plan Period and Beyond," (Washington, D.C.: ICCT, 2021), https://theicct.org/publications/decarbonize-china-transport-14th-5-year-plan-oct21; Tianlin Niu, Liuhanzi Yang, Lingzhi Jin, Zhenying Shao, Xiaoli Mao, and Zhihang Meng, "China Clean Diesel Program: Benchmarking with International Best Practices and Policy Recommendations," (Washington, D.C.: ICCT, 2023), https://theicct.org/publication/china-clean-diesel-iii-jan23/.

7 World Resources Institute, "Synergic Control Measures for Carbon and Air Pollutants Emissions from Guangdong On-Road Transportation Sector," 2022.

8 Shiyue Mao, Yichen Zhang, Georg Bieker, and Felipe Rodríguez, "Zero-Emission Bus and Truck Market in China: A 2021 Update," (Washington, D.C.: ICCT, 2023), https://theicct.org/publication/china-hvs-ze-bus-truck-market-2021-jan23/.

9 Tianlin Niu and Yunxiao Mao, "Zero-emission truck market developments and opportunities in Sichuan province China," (Washington, D.C.: ICCT, 2023), https://theicct.org/publication/zero-emission-truck-developments-sichuan-jun23/.

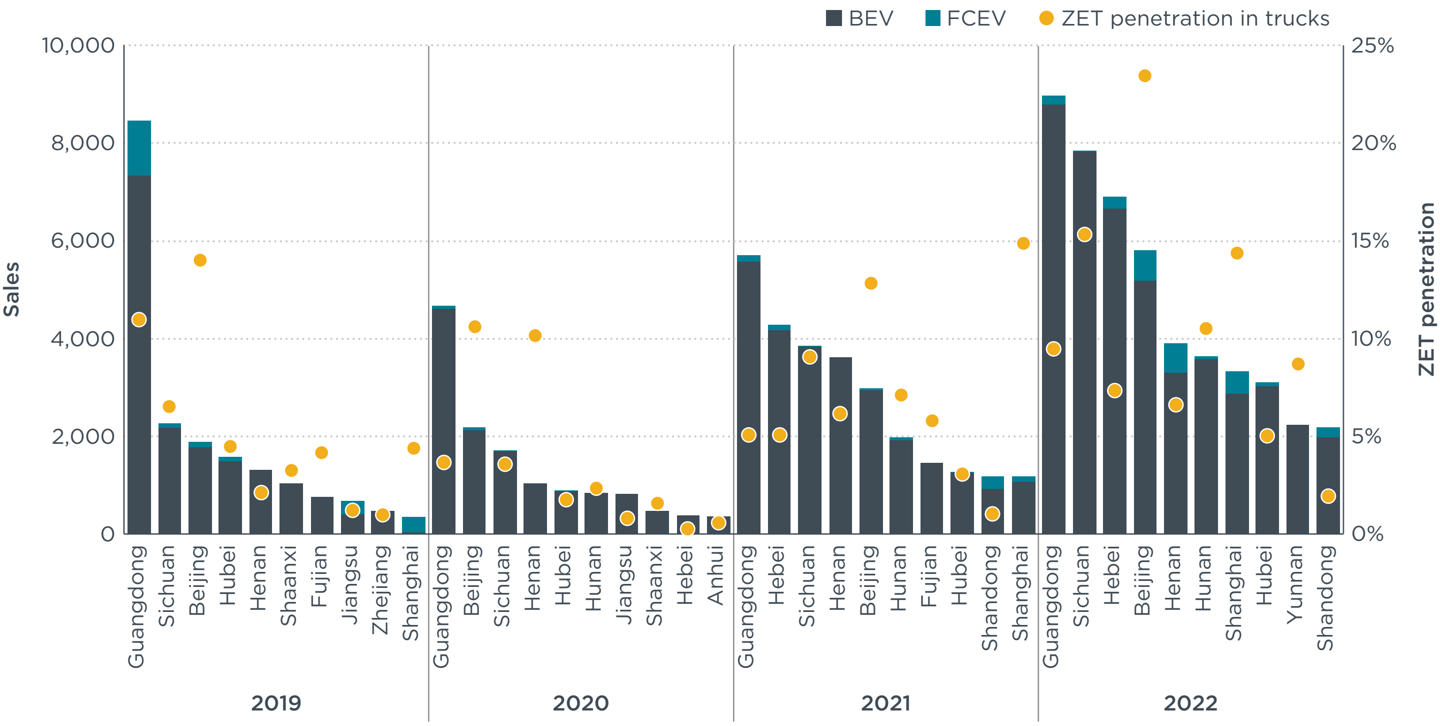


Figure 1. Top 10 provinces by new ZET sales in China, 2019–2022.

Table 1 summarizes policy measures in Guangdong province that promote the ZET market. As a key province for the hydrogen industry and a hydrogen city cluster, Guangdong provides a purchase subsidy of up to ¥250,000 for FCETs sold during the 14th Five-Year Plan period; the plan limits subsidies to the first 10,000 FCETs sold, and these must comply with the national comprehensive evaluation for fuel-cell electric vehicles and have at least five key parts manufactured within the hydrogen city cluster.[10]

Table 1. Provincial-level policies in Guangdong to promote ZETs.

Document	Policy or target
• The 14th Five-Year Plan of Guangdong province for comprehensive transportation system • The 14th Five-Year Plan for Energy[a] • The 14th Five-Year Plan for the Development of Charging Infrastructure[a] • FCET industry development program[b] • FCET demonstration city cluster program	• 20% NEV sales • 1.6 million BETs registered by 2025 • >4,500 centralized charging stations and >250,000 public charging piles by 2025 • 300 hydrogen station in by 2025 • 10,000 FCETs will be subsidized by ¥3,000/kW according to the rated power of the fuel cell system and at most ¥250,000 for each

[a] People's Government of Guangdong Province, "Guangdong 5-Year Plan of Energy," April 13, 2022, http://www.gd.gov.cn/gkmlpt/content/3/3909/post_3909371.html#8.

[b] Guangdong Development and Reform Commission, "Guangdong Implementation Plan for Accelerating the Development of Hydrogen Fuel Cell Vehicle Industry," November 12, 2020, http://drc.gd.gov.cn/ywtz/content/mpost_3125347.html.

10 People's Government of Guangdong Province, "Guangdong Action Plan for Accelerating the Construction of Fuel Cell Vehicle Demonstration City Clusters (2022-2025)," August 12, 2022, http://drc.gd.gov.cn/gkmlpt/content/3/3993/post_3993253.html#877.

City-level sales and incentives

Figure 2 shows city-level ZET sales for Guangdong province from 2019 to 2022. Shenzhen is the dominant city, home to 76% of total ZET sales in the past 4 years. Guangzhou, Dongguan, and Foshan follow with 15%, 3%, and 3% of the sales over that period. In 2022, 21 cities in Guangdong had some ZET sales, up from just four cities in 2019.

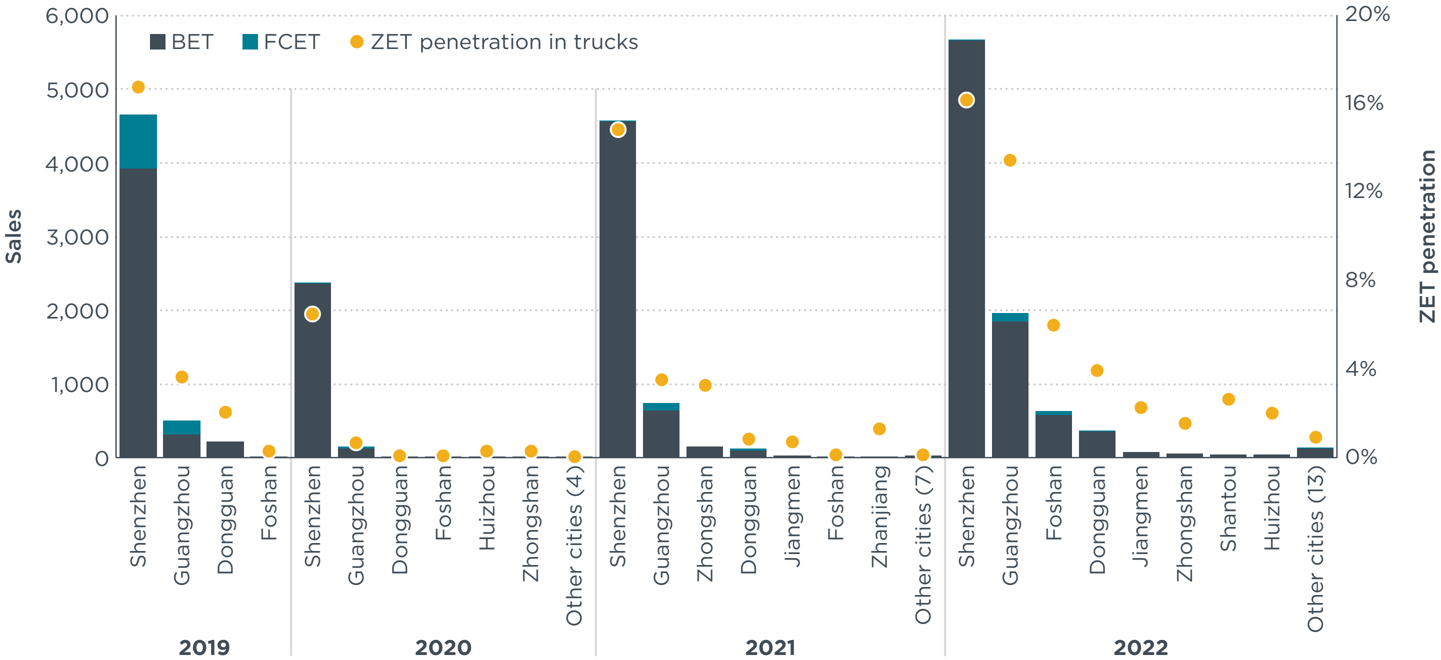


Figure 2. City-level ZET sales in Guangdong province, 2019–2022.

The key city-level ZET promotion policies in Shenzhen, Guangzhou, and Foshan in Table 2 were identified as part of a local investigation we conducted in cooperation with the Guangdong Academy of Environmental Sciences (AES; hereafter "the local investigation").[11] Such policies appear strongly correlated with sales. Shenzhen's battery electric dump truck purchase subsidy was as high as ¥800,000 (~US$115,000) before 2020; when the subsidy stopped in 2020, ZET sales dropped significantly. Another incentive in 2021 coincided with increased sales, but sales declined again in 2022 when there was no incentive. Guangzhou and Foshan introduced substantial financial incentives in 2022—up to 60% of a truck's retail price—and there ZET sales increased significantly in 2022.

11 Guangdong Academy of Environmental Sciences, "Policy Review and Best Practices of Guangdong ZET Promotion," (2022), internal consultant report for the ICCT.

Table 2. ZET promotion policies in Shenzhen, Guangzhou, and Foshan by the end of 2022.

City	Document	Subsidies and targets	Road privilege and incentives
Shenzhen	• Subsidy (2018–2019)[a] • Work plan for promotion and application of NEVs (2021–2025)[b]	• 2018 and 2019 • ¥800,000 for buying a battery electric dump truck • Replacing a diesel dump truck with BET, ¥8,000–¥142,000, and with FCET, ¥121,000–¥220,000; determined by vehicle specifications • 2021 • Additional subsidy of at most 50% national subsidy for BETs, and 100% national subsidy for FCETs • 60% NEVs of newly registered vehicles in 14th Five-year Plan • 1 million NEVs, 43,000 fast charging piles, and 790,000 slow charging piles by 2025	• Introduce electric dump truck road privilege for daytime. • At most 2 hours free parking
Guangzhou	• NEV purchase subsidy policy plan[c] • Hydrogen industry development plan (2019–2030)[d] • The 14th Five-Year Plan for the innovative development of intelligent and NEVs[e] • Promotion and application of FCET demonstration (2022–2025)[f] • The 14th Five-Year Plan for charging infrastructure	• Before 2020 • Till July 2019, at most 60% of vehicle retail price for buying NETs • After 2021 • >30% FCET in public transportation and sanitation and 5,000 pilot FCET by 2025 • 4 green hydrogen electricity integrated peaking power stations and more than 50 hydrogen stations by 2025 • 10 green hydrogen electricity integrated peaking power stations and more than 100 hydrogen stations by 2025. • 50% market penetration rate of NEVs, 800,000 total number of NEVs sold, accounting for more than 20% of all vehicles • At most ¥35/kg for FCEVs by 2025 • 50,900 public charging pile by 2025	• Free parking for certain public charging stations
Foshan	• Foshan Hydrogen Industry Development Plan (2018–2030)[g] • Funding management method for operations of Foshan new energy urban delivery trucks[h]	• ¥3 billion hydrogen industry funding for providing subsidies to FCEVs and hydrogen stations • Up to ¥70,000 for replacing diesel trucks with FCETs in 2022, specific to Nanhai district • 6,000 FCETs, 30 hydrogen stations, and 20 t per day of hydrogen production capacity by 2025 • 18,000 FCETs, 80 hydrogen stations, and 50 t per day of hydrogen production capacity by 2035 • 2023 to 2025, up to ¥30,000 operational subsidy for BETs and ¥115,000 for buying FCETs	• 50% toll fee off for fuel-cell logistic trucks • Introduce road privilege in central city area for FCETs

[a] Shenzhen Development and Reform Commission, "Shenzhen's Plan on First Batch of Electric Dump Trucks (2018-2019) for Operating Mileage Assessment and Excess Emission Reduction Incentives," January 6, 2021, http://www.sz.gov.cn/zfgb/zcjd/content/post_8394661.html.

[b] Shenzhen development and reform commission, "Shenzhen Work Plan for Promotion and Application of New Energy Vehicles (2021-2025)," March 31, 2021, http://fgw.sz.gov.cn/zwgk/qt/tzgg/content/post_8662484.html.

[c] People's Government of Guangdong Province, "Guangzhou Local Financial Subsidy Standard for New Energy Vehicle Purchase in 2019 and 2020," August 28, 2019, http://fgw.gz.gov.cn/zfxxgk/zfxxgkml/zfxxgkml/bmwj/qtwj/content/post_3883790.html.

[d] People's Government of Guangdong Province, "Guangzhou Hydrogen Energy Industry Development Plan (2019-2030)," June 2020,. http://fgw.gz.gov.cn/attachment/0/100/100172/6477212.pdf.

[e] People's Government of Guangdong Province, "Guangzhou 5-Year Plan of Intelligent and New Energy Vehicle Innovation And Development," December 27, 2021, https://www.gz.gov.cn/zwgk/ghjh/fzgh/ssw/content/mpost_8005831.html.

[f] People's Government of Guangdong Province, "Guangzhou Working Plan of Fuel Cell Vehicle Demonstration Application (2022-2025)," December 6, 2022, http://fgw.gz.gov.cn/gkmlpt/content/8/8697/mpost_8697333.html#16112.

[g] People's Government of Foshan, "Foshan Hydrogen Energy Industry Development Plan (2018-2030)," December 10, 2018, http://www.foshan.gov.cn/zwgk/zfgb/szfhj/content/post_1738589.html.

[h] Foshan Transportation Bureau, "Funding Management Method for Operations of Foshan New Energy Urban Delivery Trucks," 2022, http://jtys.foshan.gov.cn/gkmlpt/content/5/5211/post_5211562.html#374.

Foshan provided a subsidy for FCETs of up to ¥70,000 per truck in 2022, and there is a more detailed subsidy scheme from 2023 to 2025. Subsidy amounts (summarized in Table 3) depend on a truck's weight, a company's revenue, and Foshan's green operation incentive coefficient, which decreased from 1 to 0.7 between 2021 and 2025.[12]

12 People's Government of Foshan, "Foshan Municipal Financial Subsidy Fund Administration for Fuel Cell Vehicles," September 18, 2020, http://www.foshan.gov.cn/zwgk/zcwj/gfxwj/bmgfxwj/content/post_4498617.html.

Table 3. Subsidies scheme in Foshan.

		By 2022	2023	2024	2025
Replacement subsidy for FCETs in Nanhai district (¥)					
Municipal engineering vehicles and logistics vehicles	31 t and above	70,000	60,000	40,000	30,000
	25–31 t	50,000	40,000	30,000	10,000
	12–25 t	30,000	20,000	10,000	
Material delivery vehicles	7 t and above	30,000	30,000	20,000	10,000
	5–7 t	20,000	20,000	10,000	
	1.5–5 t	10,000	10,000	10,000	
Green operation incentive coefficient		1	0.9	0.8	0.7
Operational subsidy, ¥ (¥/km)					
BET	4.5–12 t vans	—	30,000 (1.0)		
	4.5 t and below	—	24,000 (0.8)		
	Refrigerated trucks	—	18,000 (0.6)		
FCET	4.5–12 t trucks	—	115,000 (2.3)		
	4.5 t and below	—	100,000 (2.0)		
	Refrigerated trucks	—	75,000 (1.5)		

ZET sales and market penetration by truck type

Figure 3 illustrates the distribution of new BETs sold in Guangdong in 2021 by city and vehicle type. This rest of this study focuses on the three most representative types of trucks based on sales: logistics trucks, dump trucks, and tractor-trailers; all other types are classified as "other trucks."[13] Logistics trucks were almost 58% of sales, and dump trucks and tractor trailers combined to make up just 14% of sales.

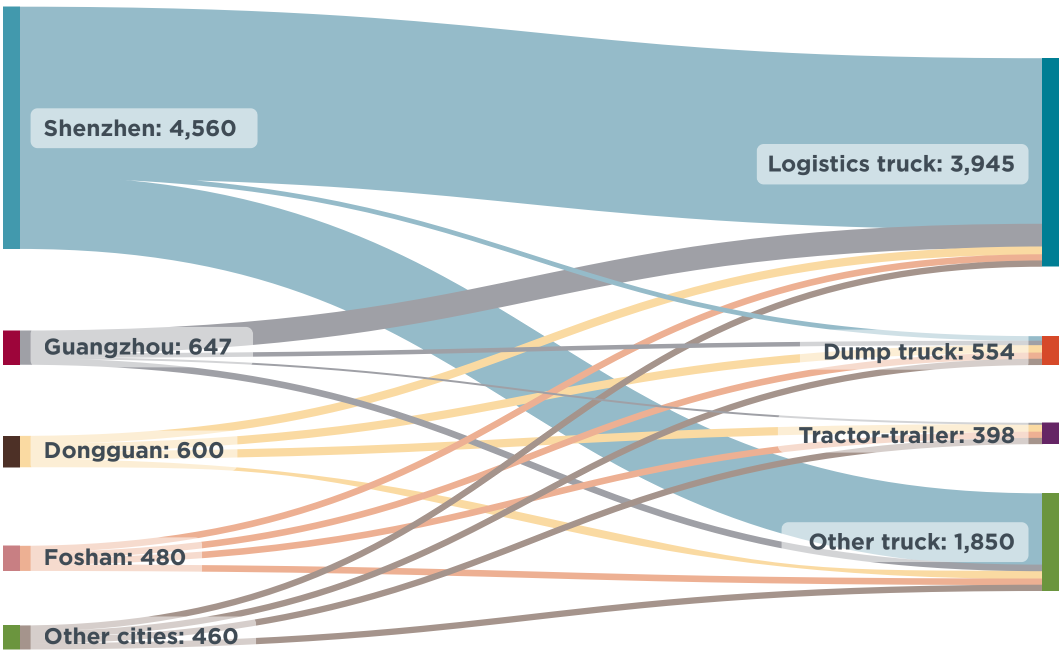


Figure 3. 2021 BET sales distribution by city and type in Guangdong.

13 This study defines logistics trucks as van trucks with GVW between 3.5 and 4.5 tons, in line with the national standard *GB/T 29912-2013 3705*. Other trucks include rigid trucks, box trucks, and utility or vocational vehicles such sanitation trucks, ambulances, and cement trucks.

Figure 4 highlights that conventional diesel trucks continue to dominate the truck market, particularly in the tractor-trailer segment. Of the cities analyzed, only Shenzhen had any substantial penetration of ZET sales; Guangzhou and other cities had little ZET penetration.

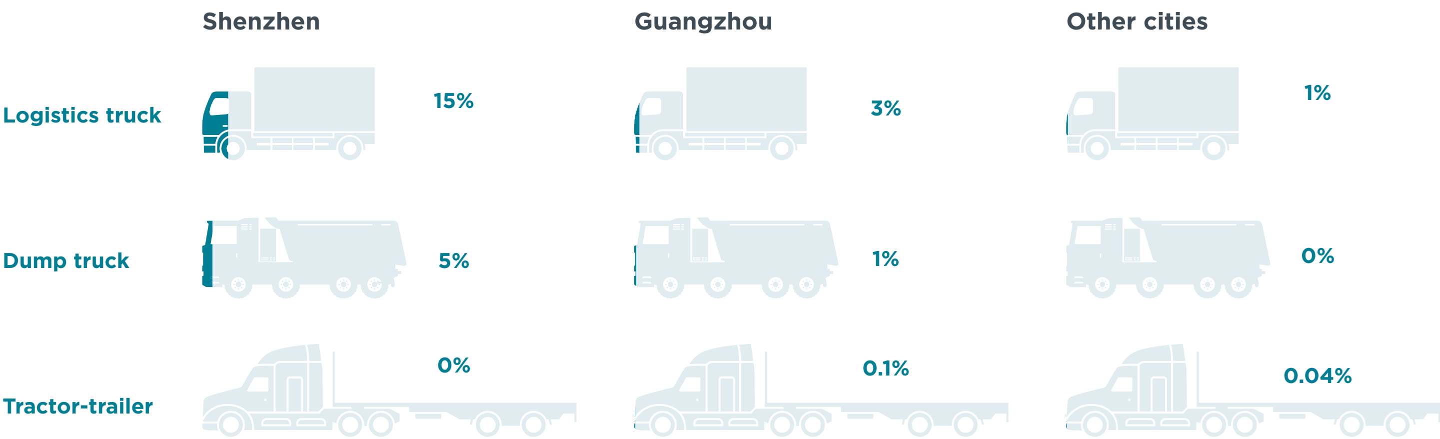


Figure 4. 2021 ZET sales penetration by city and major type in Guangdong. The shade indicates the portion of ZETs in new sales.

Other incentives related to ZET promotion

In addition to financial subsidies and road-access privileges, cities in Guangdong have implemented complementary measures to promote ZETs, including incentives for infrastructure. Both the provincial and city governments in Guangdong offer subsidies of up to ¥5 million for each charging station and hydrogen station, as detailed in Tables 4 and 5. All city subsidies are provided in addition to provincial subsidies.

Table 4. Charging facility subsidies in Guangdong, Shenzhen, Guangzhou, and Foshan.

	DC charging pile	AC charging pile
Provincial level		
Guangdong	**2016–2018:** at most ¥550/kW **2019–2020:** at most ¥300/kW **2021–2023:** at most ¥200 or ¥300/kW for different area	**2016–2018:** at most ¥100/kW **2019–2020:** at most ¥60/kW **2021–2023:** at most ¥40 or ¥60/kW for different area
City level		
Shenzhen	**2016 and before:** ¥300/kW **2017–2018:** ¥600/kW **2019–2020:** ¥400/kW	**2016 and before:** ¥150/kW for power over ¥400 kW **2017:** ¥300/kW **2018:** ¥300/kW for power over 40 kW and ¥200/kW for power below 40 kW **2019–2020:** ¥200/kW for power over 40 kW and ¥100/kW for power below 40 kW
Guangzhou	**2020 and before:** ¥550/kW **2021:** ¥100–¥125/kW	**2020 and before:** ¥150/kW **2021:** ¥15–20/kW
Foshan	**2016–2018:** at most ¥150/kW **2019–2020:** at most ¥250/kW	**2016–2018:** at most ¥30/kWh **2019–2020:** at most ¥40/kW

Table 5. Hydrogen station subsidies offered by Guangdong province, and by Shenzhen, Guangzhou, and Foshan.

	Comprehensive energy supply station	Stationary hydrogen station	Skid mounted hydrogen station	Operation subsidy
Provincial level				
Guangdong	¥2.5 million	¥2 million	¥1.5 million	
City level				
Shenzhen	Same subsidy additional to the provincial subsidy			
Guangzhou	¥2.5 million (For over 500 kg)	¥2 million (For over 500 kg)	¥0.5 million (For over 500 kg)	**2021:** ¥20/kg for retail price lower than ¥35/kg **2022–2023:** ¥15/kg hydrogen subsidy for retail price lower than ¥30/kg
Foshan		**2019 and before:** ¥5 million for newly built and ¥4 million for rebuilt (for over 500 kg), ¥8 million for newly built and ¥6 million for rebuilt (for under 500 kg) **2020 and after:** ¥3 million for all (for over 500 kg), ¥5 million for newly built and ¥4.5 million for rebuilt (for under 500 kg)	**Before 2019:** 2.5 million for newly built and ¥2 million for rebuilt (for over 350 kg) **2023:** ¥10/kg	**2018–2021:** ¥20/kg for retail price lower than ¥40/kg 2022-2023: ¥18/kg hydrogen subsidy for retail price lower than ¥36/kg

Technical viability of ZETs in Guangdong

This section examines the current ZET models in Guangdong to determine their capacity to meet local demand and replace conventional diesel trucks. Tables 6, 7, and 8 present the key technical specifications for the top-selling diesel, battery-electric, and fuel-cell logistics trucks, dump trucks, and tractor-trailers in Guangdong in 2021.[14] Vehicle specifications indicate that the payload capacity of BETs and FCETs is lower than that of diesel trucks with similar gross vehicle weight (GVW) or gross combined weight (GCW), particularly for dump trucks and tractor-trailers.

Table 6. Top-selling diesel, battery electric, and fuel-cell electric logistics trucks in Guangdong in 2021.

	Diesel	Battery electric	Fuel-cell electric
Vehicle Model	JX5042XXYXGE2	DNC5047XXYBEVK1	DLP5040XXYFCEVT20H
OEM	JMC	Yuancheng	Deshuai
Sales (2021)	4,095	1,019	3
GVW (kg)	4,495	4,495	4,495
Payload (kg)	1,495	1,415	695
Engine power (kW)	85	100	110
Engine displacement (L)	2.8	—	—
Electric range (km)	—	360	480

14 All information is from an open-source website, www.chinacar.com.cn.

Table 7. Top-selling diesel, electric, and fuel-cell electric dump trucks in Guangdong in 2021.

	Diesel	Battery electric	Fuel cell electric
Vehicle Model	LZ3310H5FB	BYD3310C2EV1	NJL3311ZHJFCEV3
OEM	Dongfeng	BYD	Skywell
Sales (2021)	1,057	100	200
GVW (kg)	31,000	31,000	31,000
Payload (kg)	16,030	13,820	14,070
Engine power (kW)	243	380	360
Engine displacement (L)	8.4	—	—
Electric range (km)	—	270	450

Table 8. Top-selling diesel, electric, and fuel-cell electric tractor-trailers in Guangdong in 2021.

	Diesel	Battery-electric	Fuel-cell electric
Vehicle Model	ZZ4256V324HE1B	CGC4250BEV1Z4	NJL4250ZEKFCEV1
OEM	Shandeka	Dayun	Skywell
Sales (2021)	2,155	10	3
GCW (kg)	48,400	48,505	48,870
Traction mass[a] (kg)	40,000	35,805	37,870
Engine power (kW)	400	355	320
Engine displacement (L)	12.4	—	—
Electric range (km)	—	240	390

[a] Traction mass is the sum of the mass of the trailer and total payload.

Engine power

In this study, we classified trucks into four weight segments (Figure 5). All diesel logistic trucks have a GVW of 3.5 t to 4.5 t and about two-thirds of diesel dump trucks have a GVW over 30 t; the remaining one-third of dump trucks are spread across the other three weight segments. Most diesel tractor-trailers have a GCW over 30 t. All ZET logistics trucks have a GVW of 3.5 t to 4.5 t and similar power as their diesel counterparts. Most battery electric and fuel-cell electric dump trucks sold have a GVW over 30 t and higher power than diesel trucks. There are no zero-emission dump trucks in the 3.5 t to 4.5 t or 12 t to 30 t segments. All zero-emission tractor-trailers are in the over 30 t segment, and most have a power level similar to diesel counterparts. The figure also indicates that sales of zero-emission dump trucks and tractor-trailers are lower than logistics trucks.

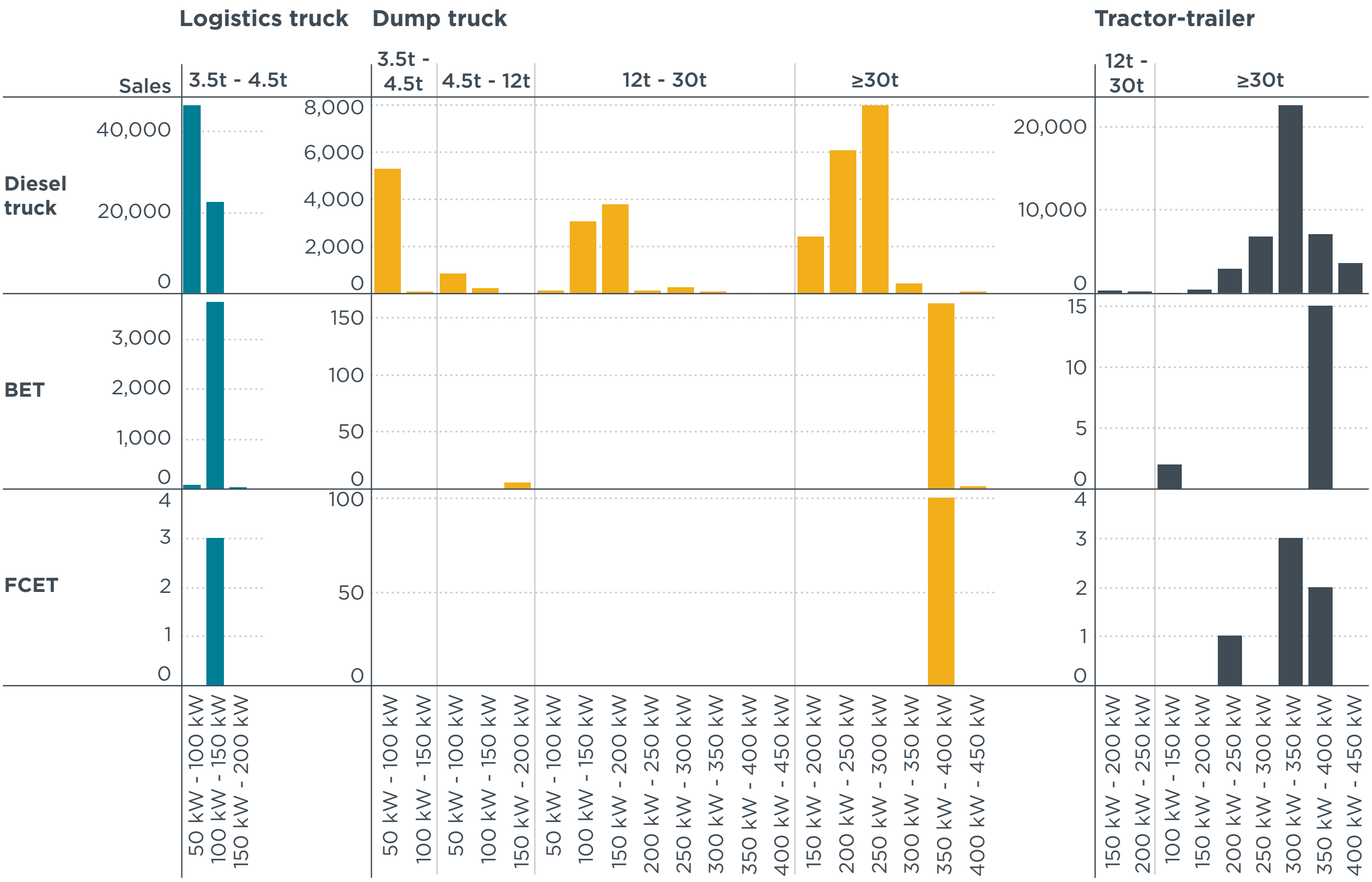


Figure 5. Sales distribution for each truck type by engine power and weight segment.

Range

The range of electric trucks is a critical factor in performance. Figure 6 depicts the range of all new BET models in 2021, with each circle representing one vehicle model. The ranges of electric logistics trucks are between 300 km and 400 km; this is sufficient for deliveries, considering the daily average mileage of 200 km to 300 km for logistics trucks in Guangzhou.[15] Electric dump trucks have ranges between 250 km and 350 km. That should be adequate for a daily average mileage of 200 km in Shenzhen and 250 km to 300 km in Guangzhou and Foshan, which was found in the local investigation. However, the average range for electric tractor-trailer models currently for sale is only 250 km, which is suitable for short-distance, but not long-haul, deliveries, which usually exceed 500 km per day.

15 Guangzhou Municipal Transportation Bureau, "Monitoring Report for Guangzhou On-Road Freight Transportation for First Half of 2020," September 7, 2020, http://jtj.gz.gov.cn/zwgg/tzgg/content/post_6531167.html.

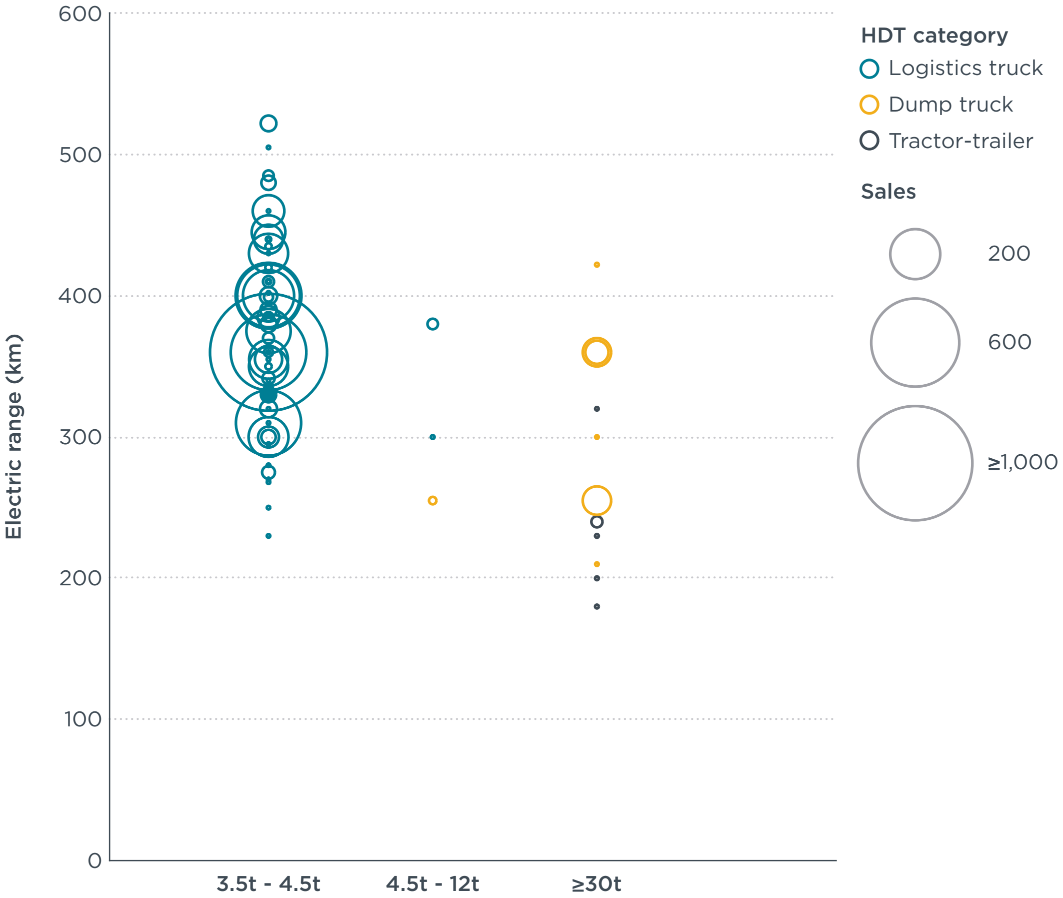


Figure 6. Range for all BETs in Guangdong.

Well-to-wheel carbon dioxide (CO_2) emissions

To compare the energy consumption of different ZETs and diesel trucks, we estimated the well-to-wheel (WTW) CO_2 emissions intensity in grams per kilometer (g/km) for the three segments: logistics trucks with a GVW of 3.5 t to 4.5 t, dump trucks with a GVW over 30 t, and tractor-trailers with a GCW over 30 t. The well-to-tank CO_2 emissions intensity for diesel trucks was estimated based on their certified energy consumption. The tank-to-wheel CO_2 emissions for diesel trucks and BETs were estimated using ICCT's Roadmap model, based on their certified energy consumption and the electricity grid mix for BETs.[16] According to Guangdong province's 14th Five-year Plan for Ecological Civilization, the current electricity grid is made up of 75.69% coal, 19.69% nuclear, 1.98% hydroelectric, 1.87% wind, and 0.77% solar.

Figure 7 depicts the distribution of WTW CO_2 emissions intensity for new trucks in 2021. More than 76% of electric logistics trucks, 90% of electric dump trucks, and 45% of tractor-trailers have lower WTW CO_2 emissions than their diesel counterparts. Furthermore, the fleet average WTW CO_2 emissions for 2021 electric logistics trucks, dump trucks, and tractor-trailers were 35%, 54%, and 28% lower, respectively, than their counterpart diesel vehicle fleets. In other words, if Guangdong had replaced all diesel trucks with BETs in 2021, the logistics truck, dump truck, and tractor-trailer fleets would have reduced WTW CO_2 emissions by 35%, 54%, and 28%, respectively. This underscores the large benefits that Guangdong could achieve with truck electrification. Assuming a cleaner power grid and higher vehicle efficiency in the future, as set out in the 14th Five-year Plan, promoting BETs can generate even larger reductions in WTW CO_2 emissions in Guangdong.

16 International Council on Clean Transportation (ICCT), "Roadmap model version 1.8," (Washington, DC, 2022), https://theicct.github.io/roadmap-doc/versions/v1.8/.

Figure 7. WTW CO_2 emissions for three typical fleets of electric and diesel trucks in Guangdong in 2021.

TCO of dump trucks in Guangzhou and Foshan

Our analysis shows that dump trucks are currently ripe for electrification. According to the local investigation, ZET dump trucks in Guangdong are used mostly for carrying construction materials and waste. A prior ICCT study showed that Shenzhen has already made progress in electrifying dump trucks.[17] In this study, we conduct a TCO analysis for trucks in Guangzhou and Foshan, two other leading cities in ZET development. The three top-selling dump truck models (shown in Table 7) were selected for the TCO study. Note that 100 BYD BETs and 200 Skywell FCETs were sold in Guangzhou and/or Foshan in 2021 and used for construction.

We further defined a typical local use case for dump trucks to make the TCO results more specific. The use case is "construction purpose," where trucks carry construction materials and waste. The daily average vehicle kilometers traveled (VKT) is 300 km, and the average payload is 70%.

17 Shiyue Mao, Hussein Basma, Pierre-Louis Ragon, Yuanrong Zhou, and Felipe Rodríguez, "Total Cost of Ownership for Heavy Trucks in China: Battery Electric, Fuel Cell, and Diesel Trucks," (Washington, D.C.: ICCT, 2021), https://theicct.org/publication/total-cost-of-ownership-for-heavy-trucks-in-china-battery-electric-fuel-cell-and-diesel-trucks/.

Methodology

This study used the ICCT's Analyzer of Zero-emission Transportation Energy and Costs (AZTEC) model; the overall methodology is illustrated in Figure 8.[18] The model can calculate the capital expenditures (CapEx) and operational expenditures (OpEx) of a single vehicle under a given use case, including specific daily mileage, average payload, energy consumption, and driving cycle. Input data such as vehicle technical specifications, vehicle efficiency, and related cost data is necessary, and by adding both CapEx and specific-year OpEx, the TCO for specific years of a vehicle can be estimated. Key data, assumptions, and results are explained in the following sections. The baseline year for analysis is 2021.

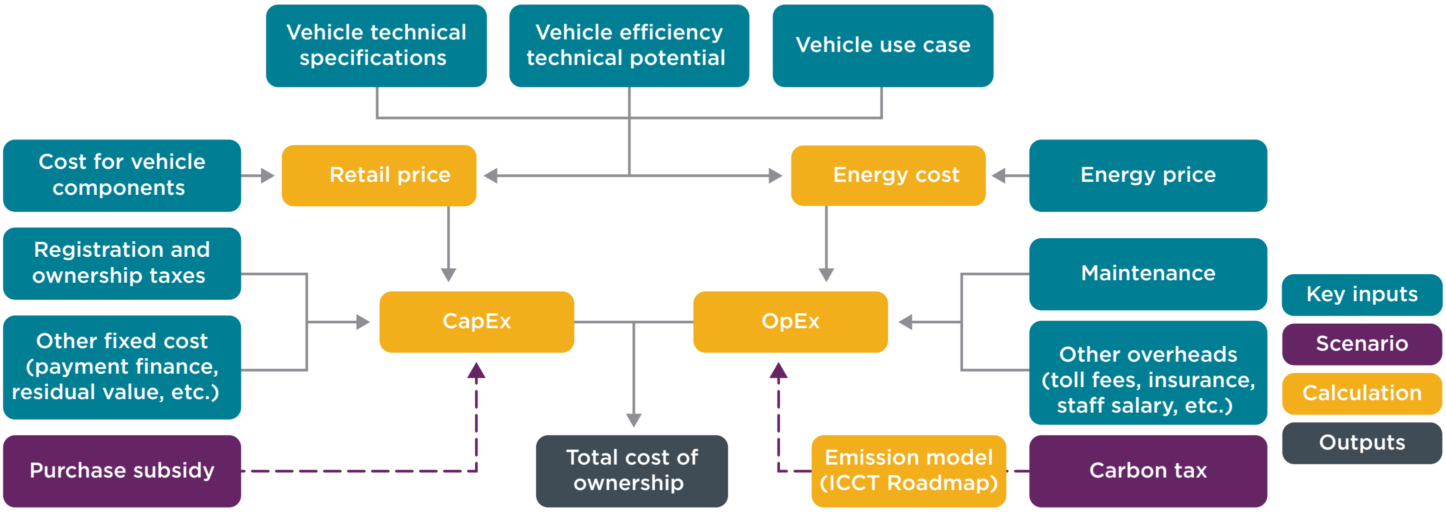


Figure 8. Methodology of ICCT's AZTEC model.

CapEx

Retail price

We found dump truck retail prices in both Guangzhou and Foshan in 2021 as follows: ¥400,000 (~US$58,000) for Dongfeng's diesel dump truck, ¥1,200,000 (~US$175,000) for BYD's battery-electric dump truck, and ¥900,000 (~US$131,000) for Skywell's fuel-cell electric dump truck. For ZETs, our market review found that the price varied across manufacturers and models. The retail price for a BET was found to be as low as ¥800,000 (~US$116,000). For an FCET, it was found to be as high as ¥1,500,000 (~US$218,000).

Retail prices depend, in part, on the manufacturing cost of each vehicle model. We applied the same methodology as was used in our Shenzhen study to estimate vehicle cost from 2021 to 2035.[19] Vehicle costs were broken down into power train (including engine, transmission, electric motor, and other power electronics), energy storage system (battery or fuel-cell pack for ZET only), and base glider (including chassis, axles, suspension, wheels, and cab).

18 International Council on Clean Transportation (ICCT), "Analyzer of Zero-emission Transportation Energy and Costs Documentation," (Washington, DC, 2022), https://github.com/theicct/AZTEC-doc.

19 Mao, Basma, Ragon, Zhou, and Rodríguez, "Total Cost of Ownership for Heavy Trucks in China: Battery Electric, Fuel Cell, and Diesel Trucks."

Diesel dump trucks

Based on our estimation, the diesel power train is about 51.7% of the total diesel truck price, and we assumed this remains constant during our study period.[20] The cost for the diesel truck's base glider was estimated to be the remainder of the truck's cost.

We adopted and calibrated the ICCT's cost curve study for diesel trucks to our projection of future vehicle efficiency, weight, and cost for diesel dump trucks.[21] Table 9 summarizes the potential efficiency technologies and additional costs we assumed for the diesel dump truck model to 2035.

Table 9. Assumptions of efficiency technologies and additional costs of diesel dump trucks

Timeline	Technology	Details	Cost (¥)	Added to
2021 to 2024	Certified to Stage 3 Fuel Consumption Standard	Peak brake thermal efficiency (PBTE): 40% + AMT	—	—
	Reduce road load	Reducing rolling resistance (RR): 26.5% and 1.4% weight	3,950	chassis
	Add 2017 best-in-class engine	PBTE: 42%	4,570	power train
2025 to	Certified to Stage 4 Fuel Consumption Standard	increase driveline efficiency by 2%	2,800	power train
	Reduce road load	Reducing 33.8% RR and 2.8% weight	4,670	chassis
	Add 2020+Engine	PBTE: 43.6%	14,660	power train
	Reduce road load	Reducing 36.8% RR and 6.9% weight	10,400	chassis
	Add waste heat recovery	PBTE: 46.2%	18,000	power train
	Reduce road load	Reducing 41.2% RR and 15.% weight	45,300	chassis
2030 to	Add 2030-era engine	PBTE: 50%	10,000	power train
2035	Add hybrid technology	Regeneration efficiency: 60%	73,300	power train

ZETs

We used estimates developed by consultants commissioned by the ICCT for the power train costs of ZETs, including the electric motor, transmission and inverter, power electronics, onboard charger, and battery thermal management system.[22] Table 10 summarizes the key cost data.

Table 10. Assumptions of key component costs for ZETs

Component	Unit	BET		FCET	
		2021	2035	2021	2035
Electric drive	CNY/kW	510.3	121.5	510.3	121.5
Power electronics	CNY/kW	182.25	182.25	182.25	182.25
Onboard charger	CNY/kW	486	486	486	486
Thermal management system	CNY/kW	141.75	141.75	60.75	60.75
Hydrogen storage tank	CNY/kg	—	—	4,500	2,000

20 Michael Fries, Maximilian Lehmeyer, and Markus Lienkamp, "Multi-Criterion Optimization of Heavy-Duty Powertrain Design for the Evaluation of Transport Efficiency and Costs," *2017 IEEE 20th International Conference on Intelligent Transportation Systems*, 2017, 1–8, https://doi.org/10.1109/ITSC.2017.8317753.

21 Dan Meszler, Oscar Delgado, and Liuhanzi Yang, "Heavy-Duty Vehicles in China: Cost-Effectiveness of Fuel-Efficiency and CO_2 Reduction Technologies for Long-haul Tractor-trailers in the 2025–2030 Timeframe" (Washington, D.C.: ICCT, 2019), https://theicct.org/wp-content/uploads/2021/06/China_HDV_long-haul_efficiency_cost_20190312.pdf.

22 Edward Anculle, Piyush Bubna, and Mark Kuhn, "E-truck Virtual Teardown Study: Final Report," (Washington, D.C.: ICCT, 2021), https://theicct.org/wp-content/uploads/2022/01/Final-Report-eTruck-Virtual-Teardown-Public-Version.pdf.

The power unit for the battery-electric dump truck model is a 445 kWh lithium-iron-phosphate (LFP) energy battery. The fuel-cell electric dump truck model has a 130 kW fuel-cell pack with a 60 kWh LFP power battery. Cost data for the energy battery and power battery for 2021 to 2023 were collected from the local investigation. All projections for the energy battery and power battery after 2023 and the cost for fuel-cell pack from 2021 to 2035 were obtained from SAE-China's Roadmap 2.0 reports and the ICCT's global study on ZET purchase costs (Figure 9).[23]

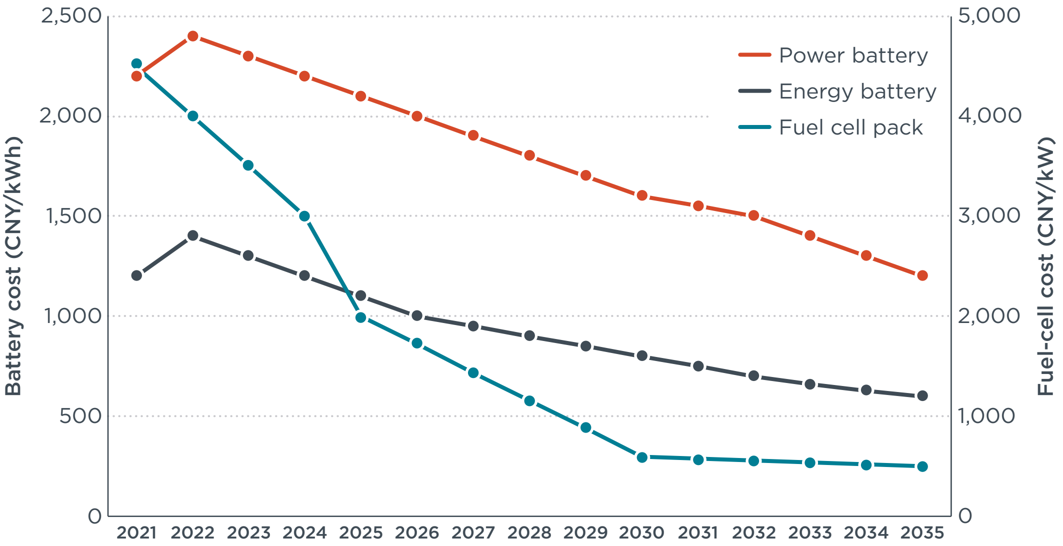


Figure 9. Battery pack and fuel-cell pack costs from 2021 to 2035.

As in our prior study for Shenzhen, power- and efficiency-specific technical potential were considered for ZETs from 2021 to 2035 (Table 11). For the efficiency technology, the same road-load reducing pathways considered for diesel trucks were applied to the chassis of the BET and FCET.

Table 11. Assumptions of the power- and efficiency-specific technical potential of BETs and FCETs

	Unit	2021	2025	2030	2035
BET					
Battery energy density	Wh/kg	160	180	210	235
Battery capacity	kWh	445	405	354	334
Curb mass	kg	17,050	16,027	14,748	13,470
Payload capacity	kg	13,820	14,843	16,122	17,401
FCET					
Fuel cell power density	W/kg	285	335	398	460
Fuel cell peak efficiency		0.5	0.55	0.6	0.6
Battery capacity	kWh	60	60	60	60
H_2 storage	kg	47	40	32	30
H_2 tank mass	kg	940	805	670	600
Curb mass	kg	16,800	15,936	14,856	13,776
Payload capacity	kg	14,070	14,934	16,014	17,094

23 Ben Sharpe and Hussein Basma, "A Meta-Study of Purchase Costs for Zero-Emission Trucks" (Washington, D.C.: ICCT, 2022), https://theicct.org/publication/purchase-cost-ze-trucks-feb22/; Ministry of Industry and Information Technology of the People's Republic of China, "Energy-Saving and New Energy Vehicle Technology Roadmap 2.0," 2021, https://www.miit.gov.cn/xwdt/gxdt/sjdt/art/2020/art_45069e679ed2437dba3d13833cefc02e.html.

Retail price validation and projection

To validate the retail price calculation methodology, we estimated the 2021 retail prices for diesel, battery electric, and fuel-cell electric trucks using the data explained in previous sections and compared the results with the investigated 2021 retail prices. The final retail price validation and projection for dump truck models in Guangzhou and Foshan are shown in Figure 10. The 2021 retail price for selected diesel, battery electric, and fuel-cell electric dump trucks are validated at ¥400,000, ¥1,200,000, and ¥900,000. The shaded area is the potential retail price range covered by the current market. The retail price for the diesel dump truck model increases 47% from 2021 to 2035 because hybridization technology (which can increase the vehicle efficiency substantially) is considered for diesel trucks. Over the same period, the retail prices of the BET and FCET decrease by 40% and 45%, respectively.

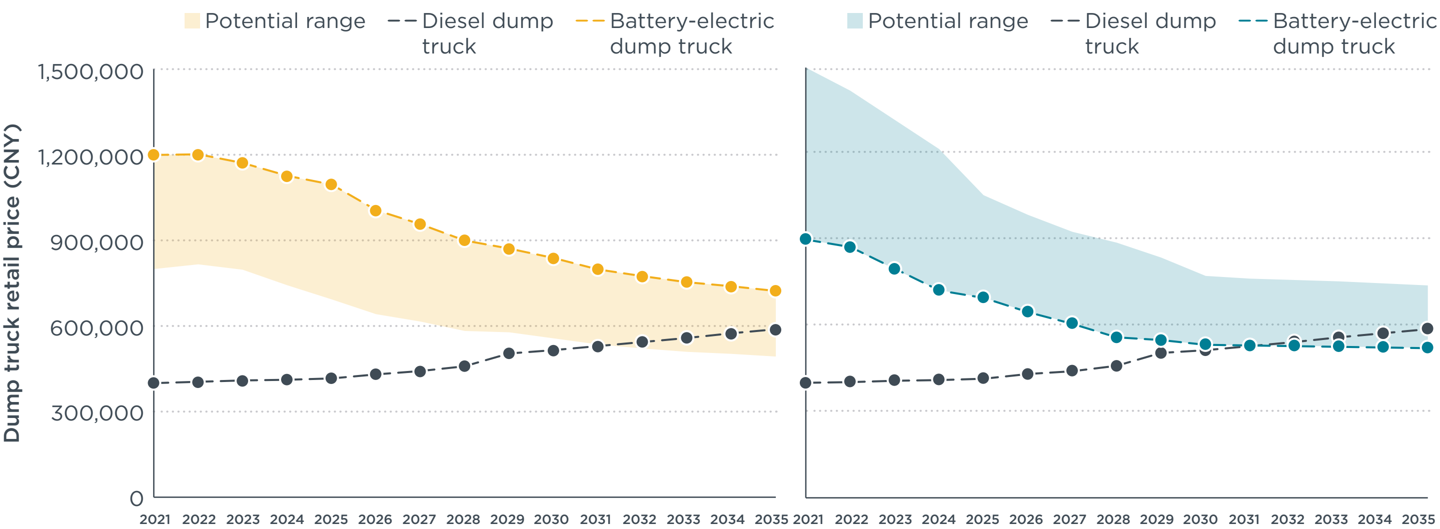
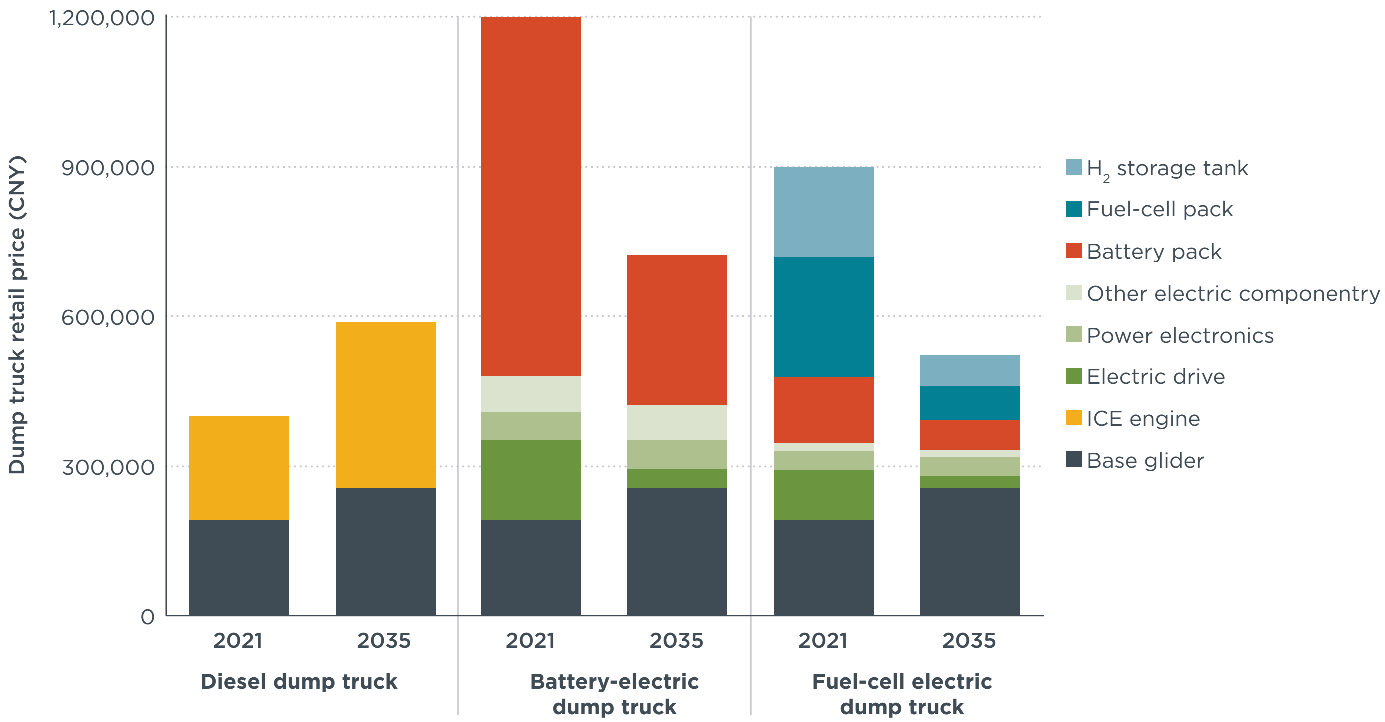


Figure 10. Projections of retail price for the BET and FCET dump truck models, 2021–2035.

Figure 11 shows the retail price components for all power trains in Guangzhou and Foshan for 2021 and 2035; the energy storage system is the key component. For the battery-electric dump truck, the share of the battery pack in the total retail price decreases from 60% in 2021 to 42% in 2035 due to battery technology improvements, while the share of the base glider increases from 16% to 30% due to efficiency technology. Similarly for the fuel-cell electric dump truck, the share of the fuel cell and battery pack in the total retail price decreases from 41% in 2021 to 25% in 2035, and the share of the hydrogen storage tank decreases from 20% to 12%.



Note: other electric componentry includes onboard charger and thermal management system.
Figure 11. Components and estimated retail price of diesel, BET, and FCET dump trucks in Guangzhou and Foshan in 2021 and 2035.

Other CapEx

Registration tax: China's tax system for trucks includes purchase and ownership taxes. Currently, conventional diesel trucks in Guangdong are subject to a purchase tax of 10% of the vehicle price. BETs and FCETs are exempt from this tax.

Payment and finance: To be aligned with the Shenzhen study, payments for all dump trucks in Guangdong were considered to be through loans. The down payment for diesel trucks was set at 50%.[24] The loan term was set at 3 years with an annual interest rate of 10%.

Discount rate: The discount rate was set 10% to be aligned with the Shenzhen study.[25]

Residual value: The local investigation and the survival curve study in a recent ICCT paper both indicated that most dump trucks will operate for around 5 years and then be sold or scrapped before reaching the mileage limitation for scrappage.[26] Thus, we considered both truck depreciation and its corresponding power depreciation.

We adopted the same data as the Shenzhen study. For unpowered dump truck depreciation, the residual value was set at 40% after 5 years. For the depreciation of battery and fuel cell packs, the 5-year residual values were estimated from Roadmap 2.0.

24 Since 2018, the People's Bank of China and the China Banking and Insurance Regulatory Commission (CBIRC) have stipulated that loan amounts for car purchases cannot exceed 70% of the price of diesel trucks and 75% of the price of BETs and FCETs.

25 Mao, Basma, Ragon, Zhou, and Rodríguez, "Total Cost of Ownership for Heavy Trucks in China: Battery Electric, Fuel Cell, and Diesel Trucks."

26 Niu, Yang, Jin, Shao, Mao, and Meng, "China Clean Diesel Program: Benchmarking with International Best Practices and Policy Recommendations."

Table 12. Battery and fuel cell pack's 5-year residual values as function of model year

	2021	2025	2030	2035
Battery pack	16%	22%	30%	40%
Fuel-cell pack	5%	25%	50%	65%

OpEx

Energy cost

The energy cost for a single truck is determined by considering the activity and energy consumption under the specific use case and the energy price. The data and methodologies for each component for our construction purpose use case in Guangdong are below.

Activity

According to the local investigation, the daily average VKT for dump trucks used for construction is 300 km, and the average payload is 70%.

Energy consumption

The baseline energy efficiency for dump trucks reflected real-world data collected by truck owners in Guangzhou and Foshan, shown in Figure 12.

Vehicle simulation models were developed in Amesim to project the energy consumption with the power train- and efficiency-specific technical potentials in Table 9 and Table 11 for the diesel dump truck, battery-electric dump truck, and fuel-cell electric dump truck models.[27] The model was validated with the baseline (2021) energy consumption by using the real-word urban delivery speed file collected in the truck testing study.[28]

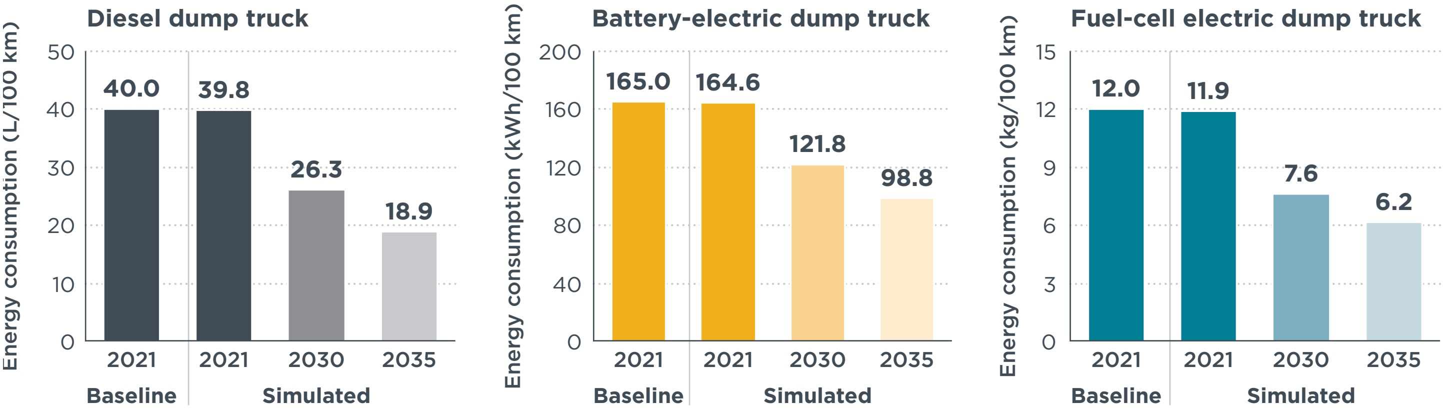


Figure 12. Baseline and projected energy consumption for dump trucks in the construction use case.

Diesel price

From September 2021 to January 2023, the daily diesel retail price in Guangzhou and Foshan varied between ¥7.28/L to ¥9.04/L (tax included), the local investigation showed. The average diesel price of ¥8.00/L was used in this study; it was considered as constant from 2021 to 2035.

27 Simcenter Amesim is a system simulation platform that allows design engineers to virtually assess and optimize the systems' performance; see Siemens Digital Industries Software, "Simcenter Amesim Software," 2023, https://plm.sw.siemens.com/zh-CN/simcenter/systems-simulation/amesim/.

28 Tianlin Niu and Felipe Rodríguez, "Recommendations for the Next Generation of China's Heavy-Duty Vehicle Emission Standard Based on Testing of China VI Vehicles," (Washington, D.C.: ICCT, 2022), https://theicct.org/publication/china-hdv-emissions-testing-oct22/.

Electricity price

Currently, all BETs in this use case in Guangdong use public fast charging. We assumed it will remain this way until 2035. Charging prices and typical charging behaviors are also assumed to remain the same until 2035. Table 12 summarizes local charging prices. Note that infrastructure maintenance fees, parking fees, and suppliers' revenues are all included in the service fee.

Table 12. Price of electricity for charging.

		Price (¥/kWh)	Use share
Basic electricity cost	Valley	0.2	90%
	Normal	0.6	8%
	Peak	1.2	2%
Service fee		0.6	

Hydrogen price

The hydrogen retail price was estimated using a formula that includes the costs for hydrogen production, transportation, and hydrogen refueling station construction and maintenance. It also includes the cost of the direct subsidy for refueling FCETs as shown in the following equation:

$$P_{H_2} = C_{production} + C_{transportation} + C_{station} - subsidy$$

Production cost was estimated based on the weighted average cost for each hydrogen production pathway in Guangdong. According to Guangdong AES' report and the development plan for the hydrogen industry in Foshan, hydrogen is mainly produced from industrial by-products and natural gas. The assumed future projected share of different hydrogen pathways is in Table 13. By-product H_2 is a by-product of chemical processes. Renewable H_2 and Grid H_2 are produced by electrolysis using renewable electricity and grid electricity, respectively. Steam-methane reforming (SMR) H_2 is produced from natural gas. For each pathway, costs include energy (including industrial electricity, coal, and natural gas) and facilities. Projections for future hydrogen production pathways were obtained from Guangdong's plans and a hydrogen study from the ICCT.[29] Costs for each hydrogen production pathway was from Zheng's study.[30]

29 Yuanrong Zhou, Zhen Zhang, and Yan Li, "Life-Cycle Analysis of Greenhouse Gas Emissions of Hydrogen, and Recommendations for China," (Washington, D.C.: ICCT, 2022), https://theicct.org/publication/china-fuels-lca-ghgs-hydrogen-oct22/.

30 Lixing Zheng et al., "基于全生命周期评价的中国制氢路线能效,碳排放及经济性研究. Research on Energy Efficiency, Carbon Emission and Economy of Hydrogen Production Routes in China Based on Life Cycle Assessment Method," *Journal of Engineering Thermophysics*, No. 9 (2022): 2305–17. https://www.nstl.gov.cn/paper_detail.html?id=2c3c4b7ee71cbff92683c192e735bd59

Table 13. Hydrogen production pathways and estimated costs, 2021–2035.

Pathway	Info	2021	2025	2030	2035
By-product H_2	Share	42.0%	50.0%	60.0%	60.0%
	Cost (¥/kg)	35.1	38.2	42.1	42.2
Renewable H_2	Share	2.0%	10.0%	30.0%	30.0%
	Cost (¥/kg)	83.3	74.1	62.6	56.6
Grid H_2	Share	0.2%	1.0%	3.0%	5.0%
	Cost (¥/kg)	32.4	30.0	27.0	24.0
SMR H_2	Share	55.8%	39.0%	7.0%	5.0%
	Cost (¥/kg)	35.1	38.2	42.1	42.2

The average transportation cost for hydrogen delivery in Guangdong in 2021 was estimated at ¥12/kg and it drops to ¥3/kg in 2035.

Hydrogen station cost is comprised of hydrogen station construction and maintenance; it was estimated at ¥14/kg in 2021 and decreases to ¥10/kg in 2035 based on the ICCT's prior study.[31]

Table 5 lists hydrogen subsidies for 2023 and earlier. Subsidies for 2024 to 2035 were projected considering the hydrogen retail price target of ¥25/kg in 2035. Estimated final hydrogen retail prices are depicted in Figure 13. Note, because there was no information on whether there is fuel tax or if hydrogen is exempt, no tax was considered.

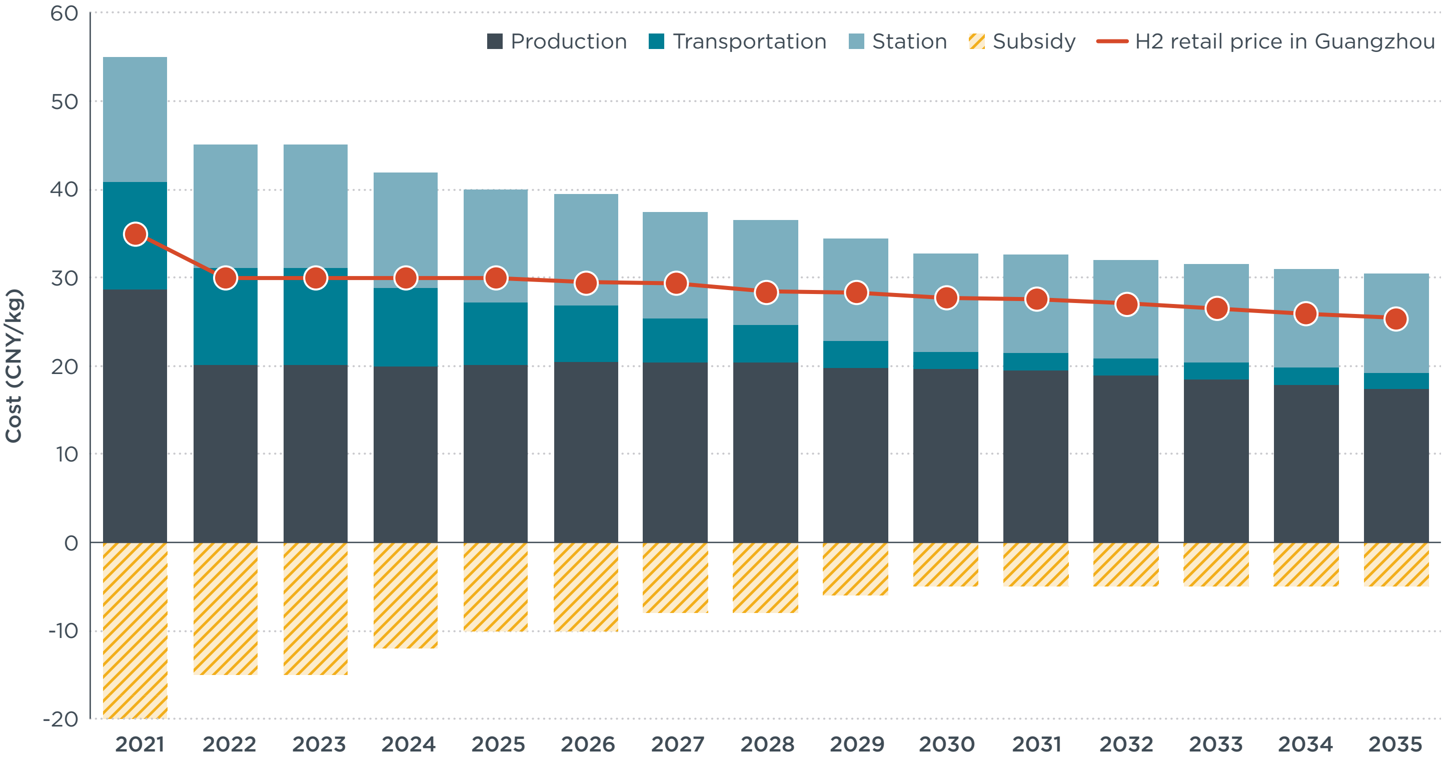


Figure 13. Hydrogen retail price at the pump in Guangdong, 2021–2035.

31 Mao, Basma, Ragon, Zhou, and Rodríguez, "Total Cost of Ownership for Heavy Trucks in China: Battery Electric, Fuel Cell, and Diesel Trucks."

Other overhead

Ownership tax: Diesel trucks are subject to an ownership tax of ¥96 per ton of curb mass per year. ZETs are exempt.

Maintenance costs: Maintenance costs vary greatly by truck application and power train technology. Based on the local investigation, maintenance costs for diesel, battery-electric, and fuel-cell electric dump trucks were estimated at ¥0.325/km, ¥0.218/km, and ¥0.228/km, respectively. These numbers do not consider replacement costs for batteries or fuel cell packs. Another variable, tire wear and changes, affects maintenance costs implicitly; differences in tire duration between electric and diesel trucks were not examined as no applicable data were found.

Parking and toll fees: According to the local investigation, there are no extra parking fees or toll fees for dump trucks in Guangzhou or Foshan. Therefore, these were not considered.

Other fees: Vehicle insurance, driver payments, staff salary, etc. are assumed to be ¥200,000 per year for diesel, battery electric, and fuel-cell electric dump trucks.

5-year TCO analysis

Policy scenarios

This study considered three policy scenarios with different financial incentives:

1. The business-as-usual (BAU) scenario represents policy measures adopted as of December 2022.
2. Policy scenario 1 (P01) introduces a purchase subsidy for battery electric and fuel-cell electric dump trucks; TCO gaps with the diesel dump truck are fully filled by the subsidy. The highest direct subsidy assumed is ¥250,000 per dump truck (lower than the amount provided by Shenzhen).
3. In policy scenario 2 (P02), an additional carbon emissions tax is charged to diesel trucks after 2025. Any TCO gap remaining after that is applied is then covered by a subsidy. In P02, the tax is charged according to the annual tailpipe GHG emissions (under 20-year global warming potential, GWP-20) and the emissions were estimated by the ICCT's Roadmap model using the above vehicle specifications and energy consumption. The carbon price was chosen based on our projection of China's future carbon market price and the carbon price proposed for European trucks (Table 14).

Table 14. Assumed carbon price for diesel trucks in Guangdong after 2025.

		2021	2025	2030	2035
Carbon tax for trucks in this study	¥/t CO_2e, GWP-20	—	50	175	250
Daily and annual charge equivalent	¥/day ¥/year	—	15 5,000	40 14,000	50 18,000
China's carbon price[a]	¥/t	5–20	25–80	84–334	284–1,134
Emission charge in Oxford, London[b]	¥/day (GBP/day)	18–90 (2–10)	36–180 (4–20)		

[a] Hongyu Zhang, Da Zhang, and Xiliang Zhang, "The Role of Output-Based Emission Trading System in the Decarbonization of China's Power Sector," Renewable and Sustainable Energy Reviews, 173 (March 2023), https://doi.org/10.1016/j.rser.2022.113080.

[b] Hussein Basma, Felipe Rodríguez, Julia Hildermeier, and Andreas Jahn, "Electrifying Last-Mile Delivery: A Total Cost of Ownership Comparison of Battery-Electric and Diesel Trucks in Europe" (Washington, D.C.: ICCT, 2022), https://theicct.org/publication/tco-battery-diesel-delivery-trucks-jun2022/.

Results

Figure 14 shows the 5-year TCO of the top-selling diesel, battery electric, and fuel-cell electric dump truck models in Guangzhou and Foshan. Both BYD's battery electric model and Skywell's fuel-cell electric model can reach the same 5-year TCO with Dongfeng's diesel truck in 2028 under the BAU scenario. With the financial incentives under P01, the TCO parity year will come earlier: 2023 for the BET and 2026 for the fuel-cell electric model. Under P02, the TCO parity year for the fuel-cell electric truck is 2025.

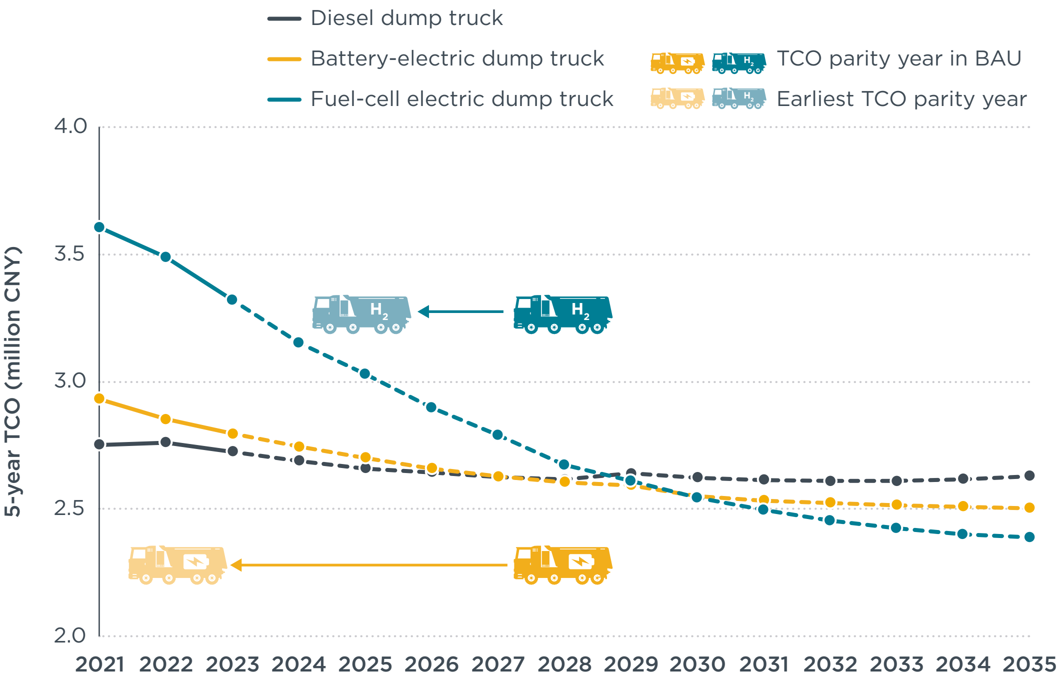


Figure 14. 5-year TCO and parity points of the top-selling diesel, battery electric, and fuel-cell electric dump truck models in Guangzhou and Foshan, 2021–2035.

Figure 15 depicts the share of CapEx and OpEx in the TCO results. Purchase and energy costs are largest. Though other OpEx costs also contribute about 40%–50% of the TCO, they have little impact on TCO differences as their values are similar for all three trucks.

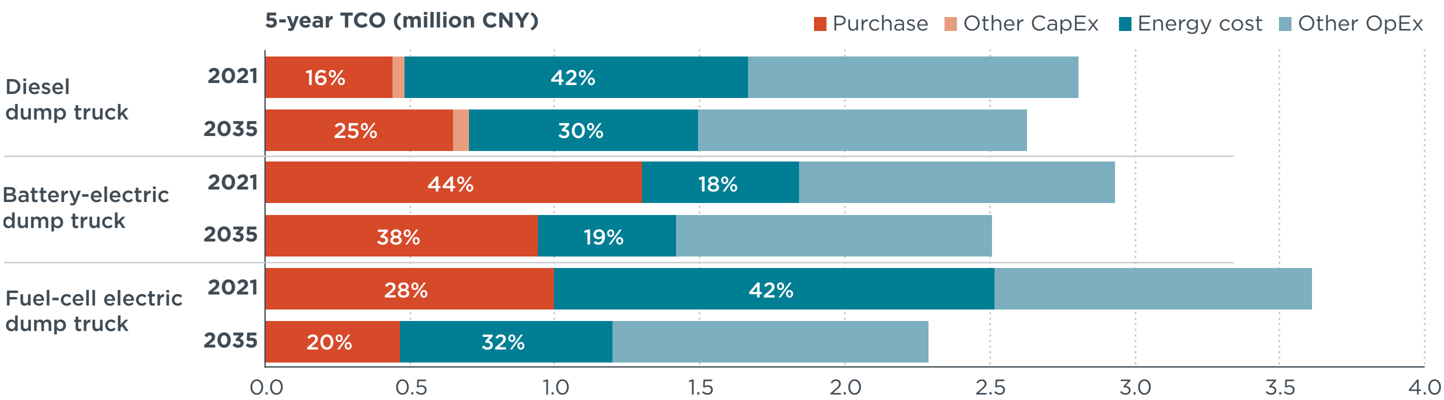


Figure 15. Components share of the 5-year TCO for diesel, battery electric, and fuel-cell electric dump trucks in 2021 and 2035.

Figure 16 details the amounts for the subsidies and carbon tax under each scenario. The striped bars represent the portions of the subsidy that may be unaffordable for the government, given their high amounts. Under P01, the government would provide a purchase subsidy to battery electric dump trucks of ¥70,000 per truck in 2023. That could drop to ¥3,500 per truck in 2027 and keep the battery electric dump truck's 5-year TCO the same as the diesel dump truck's. For fuel-cell electric dump trucks, the government could start to provide a subsidy of ¥155,000 per truck in 2026 to make the fuel-cell electric dump truck achieve TCO parity. Under P02, with the additional carbon tax, or any other equivalent daily or annual charges, the TCO gap between ZETs and diesel trucks is smaller. For BETs, the government would only provide subsidies for 2 years, and the amount can be lowered from ¥50,000 per vehicle in 2023 to ¥22,500 per vehicle in 2024. For FCETs, TCO parity can be moved 1 year ahead to 2026 compared to P01, and the subsidy drops from ¥280,000 to ¥165,000 per vehicle in 2025. The subsidies needed for 2027 and 2028 would also decrease significantly.

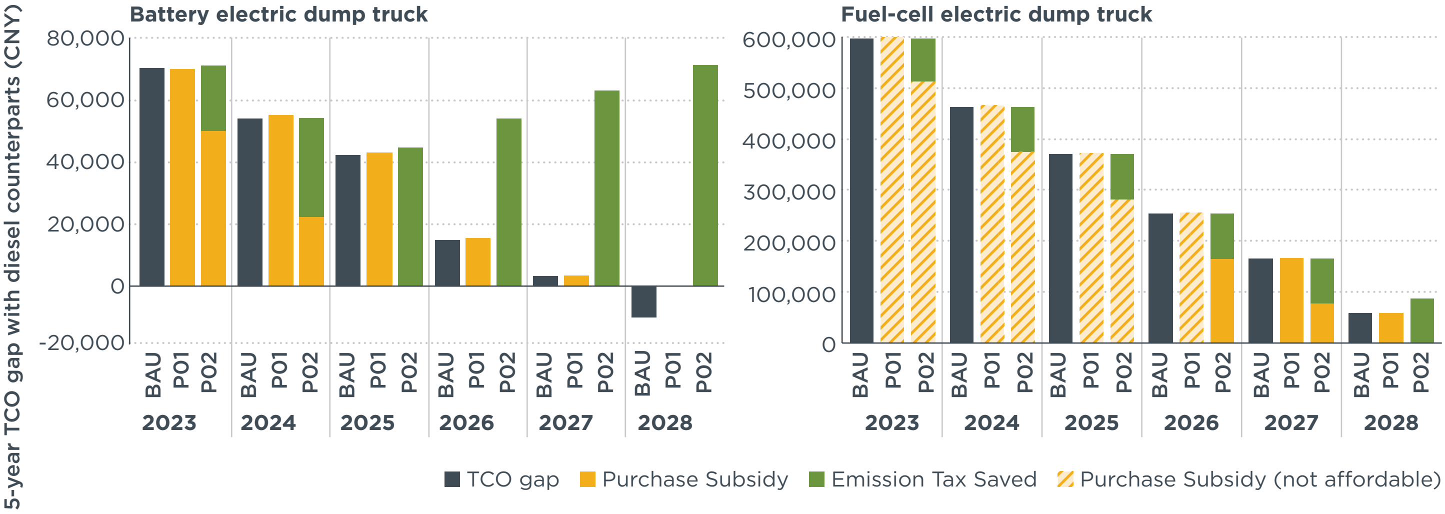


Figure 16. TCO impacts of our detailed incentive scheme including subsidies and a carbon tax.

Additionally, the dump truck fare for the construction use case was determined to be around ¥12/km (or ¥0.7/t-km), and the estimated 5-year revenue for one dump truck was estimated at ¥4,000,000. This means that the diesel, battery electric, and fuel-cell electric dump trucks used for construction are all profitable.

Sensitivity analysis on retail price

Pricing does not necessarily reflect manufacturing costs, and the popular models in Guangzhou and Foshan are likely to be among the most expensive battery electric dump truck models and among the cheapest fuel-cell electric dump truck models. As this could significantly impact the TCO results, a sensitivity analysis was conducted using the cheapest battery electric model and the most expensive fuel-cell electric mode. Results are presented in Figures 17 and 18.

Cheaper battery electric dump trucks are estimated to have already achieved TCO parity in 2021. More expensive fuel-cell electric dump trucks are projected to achieve TCO parity much later, in 2035. There is only a need, then, to develop an incentive policy to promote TCO parity for FCETs. Both P01 and P02 could expedite TCO parity from 2035 to 2030. With the additional carbon tax, the subsidy amount could be lower and it would only be needed from 2030 to 2032.

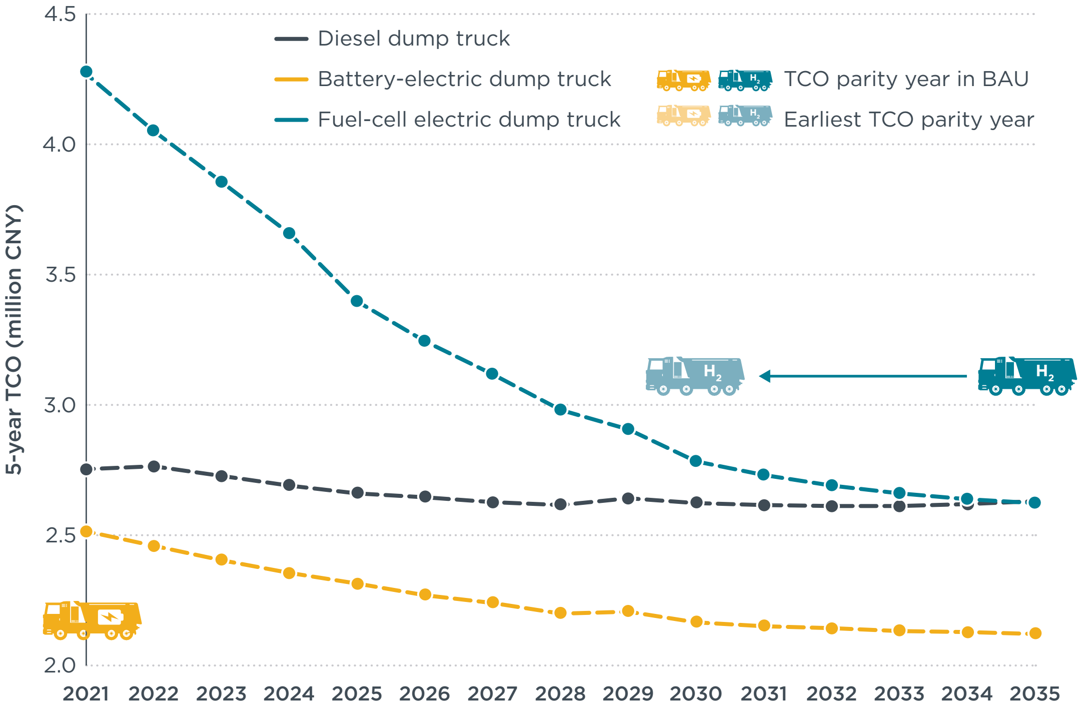


Figure 17. 5-year TCO and the parity point of the top-selling diesel dump truck, the cheapest electric, and the most expensive fuel cell dump truck models in Guangzhou and Foshan, 2021–2035.

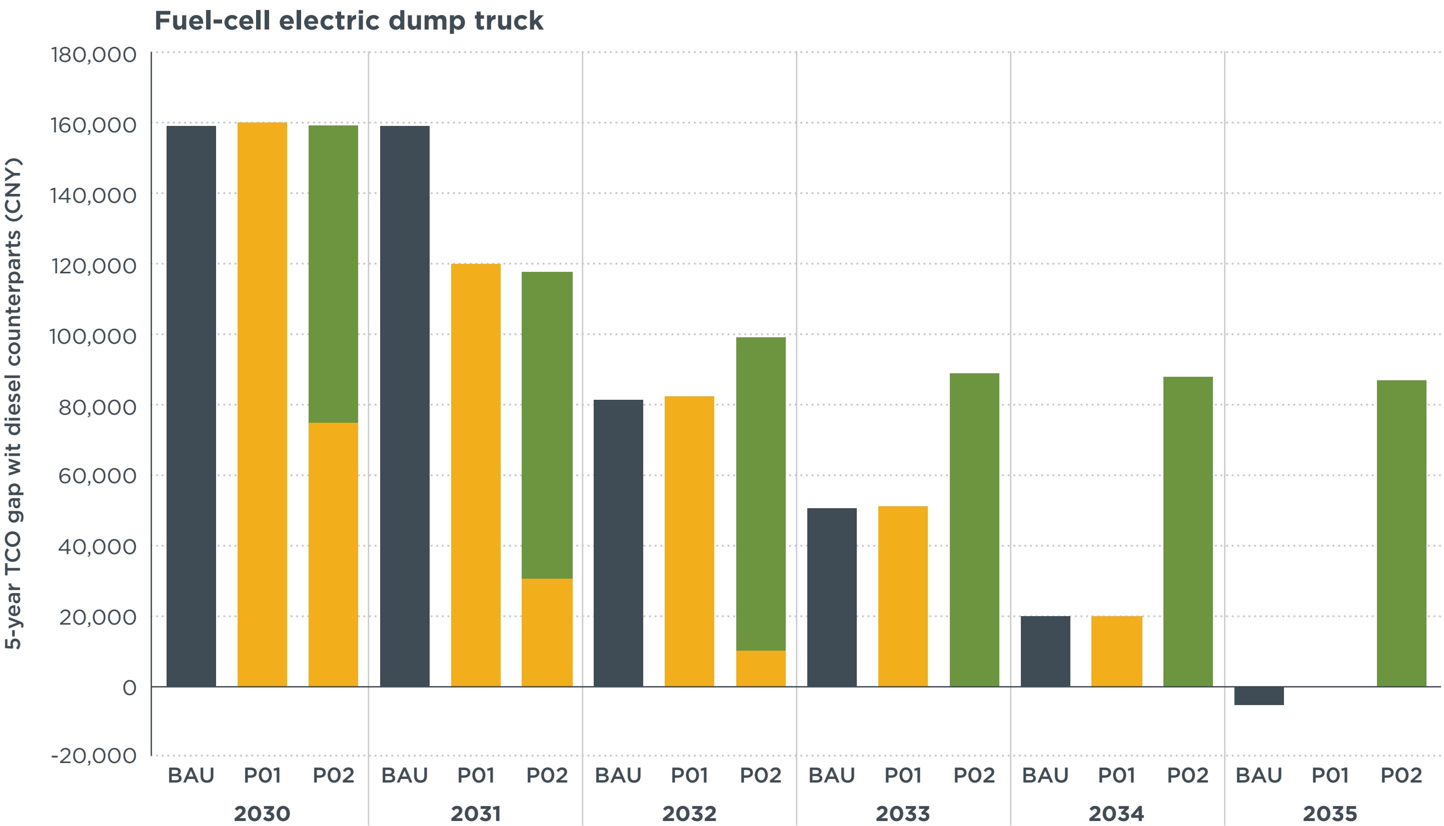


Figure 18. TCO impacts of our detailed incentive scheme for subsidies and carbon tax for the most expensive FCET model.

Conclusions and policy implications

In line with Guangdong's goals to promote HDT electrification, this study examined the state of the ZET market with a focus on policies that would promote ZET adoption, decarbonization potential, and real-world examples at both the provincial and city levels. We also conducted a comprehensive TCO analysis for dump trucks in Guangzhou and Foshan in their primary use case—transporting construction materials and waste—and investigated potential incentive schemes that could expedite TCO parity for ZETs.

We found that logistics trucks have already experienced substantial growth and commercialization in Guangdong, and for dump trucks, there are existing ZET models that can effectively replace diesel counterparts for specific use cases. The challenge lies in promoting ZET sales of dump trucks; incentive policies designed to reduce TCO can be helpful. For tractor-trailers, technical advancements beyond the current ZET models are needed to accommodate long-haul deliveries. These need to be in place before large-scale promotion policies could be effectively applied.

Cities can reduce CO_2 emissions by transitioning to BETs. We estimated that the fleet average WTW CO_2 emissions for battery electric logistics trucks, dump trucks, and tractor-trailers in 2021 were 34%, 54%, and 18% lower, respectively, compared to their diesel counterparts. As the electricity grid continues to decarbonize and vehicle efficiency improves in line with China's Carbon Peaking Plan, promoting ZETs can yield even greater WTW CO_2 emissions benefits for Guangdong in the future.

Additionally, providing purchase subsidies for ZETs and placing emissions charges on diesel trucks that are targeted toward filling TCO gaps, we estimate that the top-selling BET and FCET models in Guangzhou and Foshan could achieve TCO parity with leading diesel dump trucks as early as 2023 and 2025, respectively. ZET purchase prices and energy costs are a large part of the TCO. For trucks with the same capacity as the top-selling BET and FCET models in Guangzhou and Foshan, the BET priced at ¥800,000 achieved TCO parity with a diesel counterpart in 2021. In contrast, the more expensive FCET priced at ¥1,500,000 was estimated to reach TCO parity after 2030.

Drawing on these findings, we suggest exploring the following policies for promoting truck electrification in Guangzhou and Foshan. These can also serve as a reference for other Chinese cities:

Develop tailored incentive policies for dump trucks and tractor-trailers based on their local use cases. Given that the electric logistics truck market has already matured, prioritizing the electrification of dump trucks can be the focus until zero-emission tractor-trailer models are fully equipped for long-haul deliveries. Because the primary use case for dump trucks in Guangzhou and Foshan is carrying construction materials and waste, it could be most beneficial to focus on incentivizing this application.

Prioritize the promotion of and financial incentives for battery electric dump trucks until 2025. Direct purchase subsidies for battery electric dump trucks could start at ¥70,000 per truck in 2023 and decrease to ¥3,500 per truck in 2027 to maintain TCO parity with diesel counterparts starting from 2023. Because FCETs are projected to achieve TCO parity later, by 2025, prioritize battery electric power trains in the short term.

Following the polluter-pays principle, Guangzhou and Foshan could consider introducing emissions charges for diesel trucks like a carbon tax after 2025. A carbon tax could be set at ¥50/t CO_2e in 2025 and increase to ¥250/t CO_2e in 2035, equivalent to ¥5,000/year in 2025 and ¥18,000/day for diesel trucks in 2035. A carbon tax would not only alleviate the financial burden on governments by reducing subsidy amounts, but also expedite TCO parity for ZETs.

Implement additional targeted policies to boost the adoption of ZETs. Financial incentives for manufacturers of batteries, fuel cells, and hydrogen tanks can lower the retail price of ZETs. Policies ensuring favorable operating conditions for ZETs such as road access privileges can also improve their operational expenses.