ZEROING IN ON ZERO-EMISSION TRUCKS

The State of the U.S. Market

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CALSTART

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Unless otherwise noted, all figures are copyright CALSTART based on data from author correspondence with manufacturers, IHS Markit, MarkLines, California's Clean Off-Road Equipment Voucher Incentive Program, public press releases, California's Clean Truck and Bus Voucher Incentive Project, and the New York Truck Voucher Incentive Program. See Appendix D for more information about these data sources.

Cover image: A lineup of heavy-duty zero-emission truck models. Photo credit: Harbor Trucking Association and Marc Harris Photography

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LIST OF ACRONYMS

ACF	Advanced Clean Fleets rule
ACT	Advanced Clean Trucks rule
BET	Battery-electric truck
CaaS	Charging-as-a-Service
CARB	California Air Resources Board
CDL	Commercial driver's license
CORE	California's Clean Off-Road Equipment Voucher Incentive Project
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FCEV	Fuel cell electric vehicle
FHWA	Federal Highway Administration
GHG	Greenhouse gas
Global MOU	Global Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles
HD	Heavy-duty
HVIP	California's Clean Truck and Bus Voucher Incentive Project
IRA	Inflation Reduction Act
IRMA	Initiative for Responsible Mining Assurance
ISEF	Innovative Small e-Fleet Program
kW	Kilowatt
kWh	Kilowatt-hour
lbs.	Pounds
MCS	Megawatt Charging System
MD	Medium-duty
MHD	Medium- and heavy-duty
MOU	Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding

LIST OF ACRONYMS

NACFE	North American Council for Freight Efficiency
NOx	Nitrogen oxides
NYTVIP	New York Truck Voucher Incentive Program
OEM	Original equipment manufacturer
PM2.5	Fine particulate matter
TaaS	Truck-as-a-Service
TCO	Total cost of ownership
ZE	Zero-emission
ZET	Zero-emission truck
ZEV	Zero-emission vehicle

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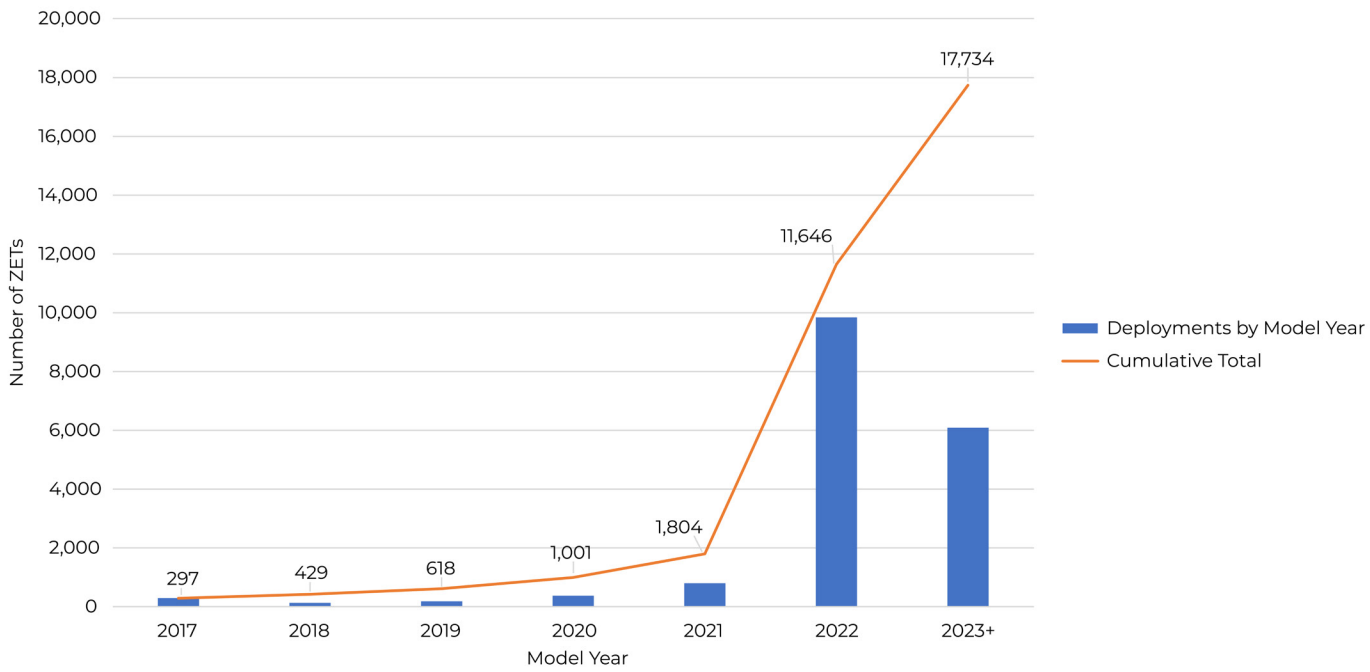
EXECUTIVE SUMMARY

Medium- and heavy-duty (MHD) freight vehicles are a top priority for decarbonizing U.S. transportation and mitigating transportation-related greenhouse gas (GHG) emissions. These vehicles play a vital role in the U.S. economy, but because of their critical high-mileage haulage of the nation's goods, they emit significant amounts of GHGs and criteria pollutants, often in the most vulnerable communities. Fortunately, existing and ever-expanding technology can eliminate tailpipe emissions and significantly reduce the overall carbon footprint of MHD vehicles. More than 160 models of zero-emission trucks (ZETs) are now available from over 40 original equipment manufacturers (OEMs), and **as of June 2023, more than 17,500 ZETs have been deployed in the United States** (Figure ES-1).[1]

Figure ES-1. U.S. ZET Deployments by Vehicle Model Year (2017–June 2023)



ZETs are defined as Class 2b-8 commercial vehicles, including cargo vans, MD step vans, MD trucks, HD trucks, refuse trucks, and yard tractors.

Data Source: CALSTART research

1 ZET data are gathered from sources outlined in Appendix D. In previous iterations of this report, "deployments" were referred to as "deployed sales" and model year served as a proxy for deployment year per IHS Markit guidance.

This recent surge can be attributed primarily to the cargo van segment, which represents more than 80 percent of all ZET deployments (Table ES-1) and has limited market barriers for mass adoption (CARB, 2023a).

Table ES-1. U.S. ZET Deployments and Market Share by Segment (As of June 2023)

Vehicle Segment	ZET Deployments	Total Stock	ZET Market Share
Cargo Van	**14,400**	3,687,740	.39%
MD Step Van	843	266,866	.32%
MD Truck	442	3,573,915	.01%
HD Truck	867	**5,104,926**	.02%
Refuse	48	118,135	.04%
Yard Tractor[2]	1,134	23,437	**4.84%**
Total	**17,734**	**12,775,019**	**.14%**

Incentives and regulations continue to be significant drivers of ZET adoption. **States that have passed the Advanced Clean Trucks (ACT) regulation[3] account for 38 percent of all ZET deployments despite making up just 25 percent of all truck registrations.** Meanwhile, ACT states in conjunction with Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding (MOU) states constitute 51 percent of all deployments. States that have had ZET incentive programs prior to 2022 encompass 39 percent of all deployments.[4]

With nearly half of ZET deployments in states without ZET regulations, the maturity of this technology is now undeniable, as well as the fact that the market has evolved to the point where fleets can deploy ZETs without incentives and regulations. In fact, for the first time ever, ZETs have now been deployed in all 50 states. These ZET deployment trends, along with the United States' signing of the Global Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles (Global MOU)[5] to enable 100 percent of new truck and bus sales be zero-emission by 2040, create a compelling market signal to OEMs and fleets to invest in ZETs.

Furthermore, investments are being made to establish dedicated infrastructure for ZETs along highly traveled trucking corridors, bolster domestic manufacturing of essential vehicle components, and further reduce lifecycle vehicle emissions by looking at upstream and end-of-life practices. Additional

2 Yard tractor deployments are likely underreported as many are not registered for on-road use and much of the data on deployments come from vehicle registrations.

3 States that have adopted the ACT rule as of June 2023 include California, Colorado, Massachusetts, New Jersey, New York, Oregon, Vermont, and Washington. New Mexico, Maryland, and Rhode Island have since become the ninth, tenth, and eleventh states, respectively, to adopt the ACT rule in late 2023, though for the purposes of this update, which includes data through June 2023, New Mexico, Maryland, and Rhode Island are not considered ACT states.

4 States considered to have ZET incentive programs prior to 2022 include California, Massachusetts, New York, New Jersey, Pennsylvania, and Washington. More information is available in Appendix A.

5 Visit the Global Commercial Vehicle Drive to Zero's website for more information about the Global MOU at https://globaldrivetozero.org/mou-nations/.

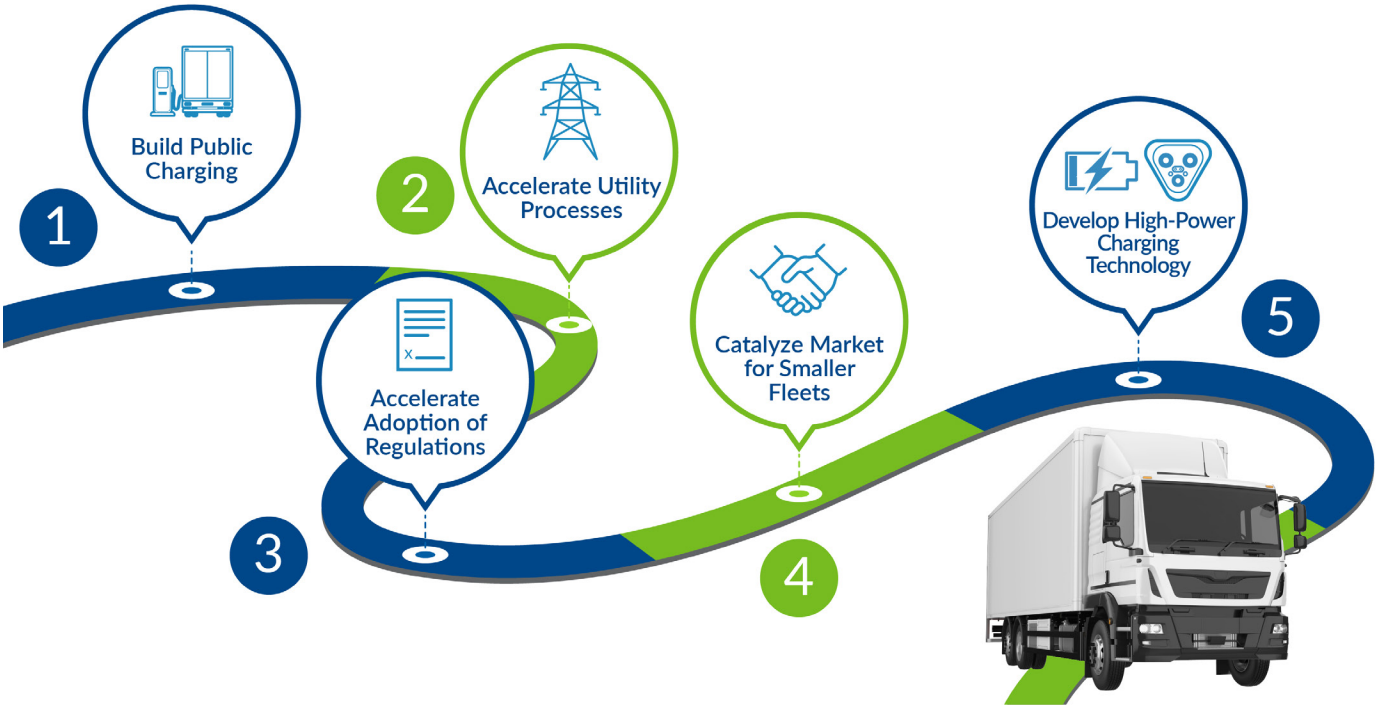
trends that are driving ZET deployments include: increased support for small fleets, increasingly large-scale deployments, shippers' increasing interest in reducing carbon emissions, and hydrogen fuel cell truck developments (Figure ES-2). As the technology continues to advance and economies of scale are achieved, ZETs will begin to dominate the U.S. truck market.

Figure ES-2. Observed 2023 U.S. ZET Market Trends

The momentum toward decarbonizing the trucking sector is indisputable. Nevertheless, sustained action and investment are essential to realize the full potential of this transformative shift (Figure ES-3). **Key opportunities to accelerate ZET deployments in the coming months and years include:**

1. **Building public charging.**
2. **Accelerating utility processes**, including grid buildout, energization of charging infrastructure, and make-ready program processing.
3. **Accelerating adoption of regulations** like the ACT rule and the U.S. Environmental Protection Agency's "Phase 3" heavy-duty GHG standards.
4. **Catalyzing a market for smaller fleets**, which includes a secondary ZET market, access to reasonable financing and insurance, and clear signals from customers.
5. **Developing high-powered charging technology.**

Figure ES-3. Top Five Actions Needed to Accelerate U.S. ZET Market



Unprecedented collaboration will be required from stakeholders across the industry, including fleets, OEMs, utilities, charging providers, shippers, regulators, policymakers, academia, nonprofits, and frontline communities. Everyone has a role to play to ensure the pace and success of this transition.

CHAPTER I

INTRODUCTION

THE U.S. TRUCKING INDUSTRY

The trucking industry plays a vital role in the U.S. economy, serving as the lifeblood of logistics and transportation. It is the backbone of commerce, responsible for moving nearly three-quarters of all the country's freight. The U.S. trucking industry also employs roughly 8.4 million people while generating more than $940 billion each year in revenue (American Trucking Association, 2023).

The industry enables the timely and efficient delivery of goods, ensuring that products reach their destinations in a reliable and cost-effective manner. Its efficient operation is critical for businesses to thrive and for individuals to access the goods they need. The importance of trucking will only grow—the freight economy is expected to increase 25.6 percent by 2030 due to population and economic growth (American Trucking Association, 2019).

The trucking industry includes many components, including goods, drivers, and the vehicles themselves. In the United States, commercial vehicles are classified according to their gross vehicle weight ratings (GVWR). This analysis considers only Class 2b (8,501–10,000 lbs.) through Class 8 (33,000 lbs. and above) trucks, which are categorized into six distinct segments: cargo vans, medium-duty (MD) step vans, MD trucks, refuse trucks, yard tractors, and all other heavy-duty (HD) trucks (Figure 1).[6] For the purposes of this report, Class 2b–8 trucks that fall into one of these segments are referred to as trucks. In addition to on-road trucks, this analysis includes yard tractors, which may not be registered as on-road vehicles but provide a critical function related to moving freight in the United States.

6 Past reports have included pickup trucks; however, they are excluded in this report since most are privately owned and not used for commercial goods movement. Buses are also not included in this analysis. For information on zero-emission transit and school bus deployments, see CALSTART's *Zeroing in on Zero-Emission Buses* and *Zeroing in on Electric School Buses* reports, respectively. New editions of both reports will be published in 2024.

Figure 1. Vehicle Segmentation

Cargo Van

Class 2b/3 Cargo Van
- Used in last-mile delivery operations
- Average 11,000 miles/year

MD Step Van

Class 3-8 Step Van
- Walk-in last-mile delivery operations
- Used in last-mile delivery operations

MD Truck

Class 3-6 Rural/Intercity
- Cargo, freight, delivery
- Combination of urban and highway traffic

Class 3-6 Work Site Support
- Utility, construction (significant idle time and PTO use)
- Heavy equipment or heavy machinery operations

HD Truck

Class 7-8 Over the Road (OTR) or Long-Haul Trucks
- Average 75,000 miles/year
- Higher average speed due to highway driving

Class 7-8 Urban/Regional Haul
- Average 35,000 miles/year
- Day cab
- Operates delivery or drayage operations

Class 7-8 Work Site Support
- Used in utility and construction
- Significant idle time and power take-off (PTO) use

Refuse Truck

Class 3-8 Refuse Truck
- Waste and recycling collection and transport
- Average 25,000 miles/year
- High frequency stopping

Yard Tractor

Class 7-8 Yard Tractor
- Moves semi-trailers within a cargo yard or warehouse
- Can qualify for either on-or off-road use

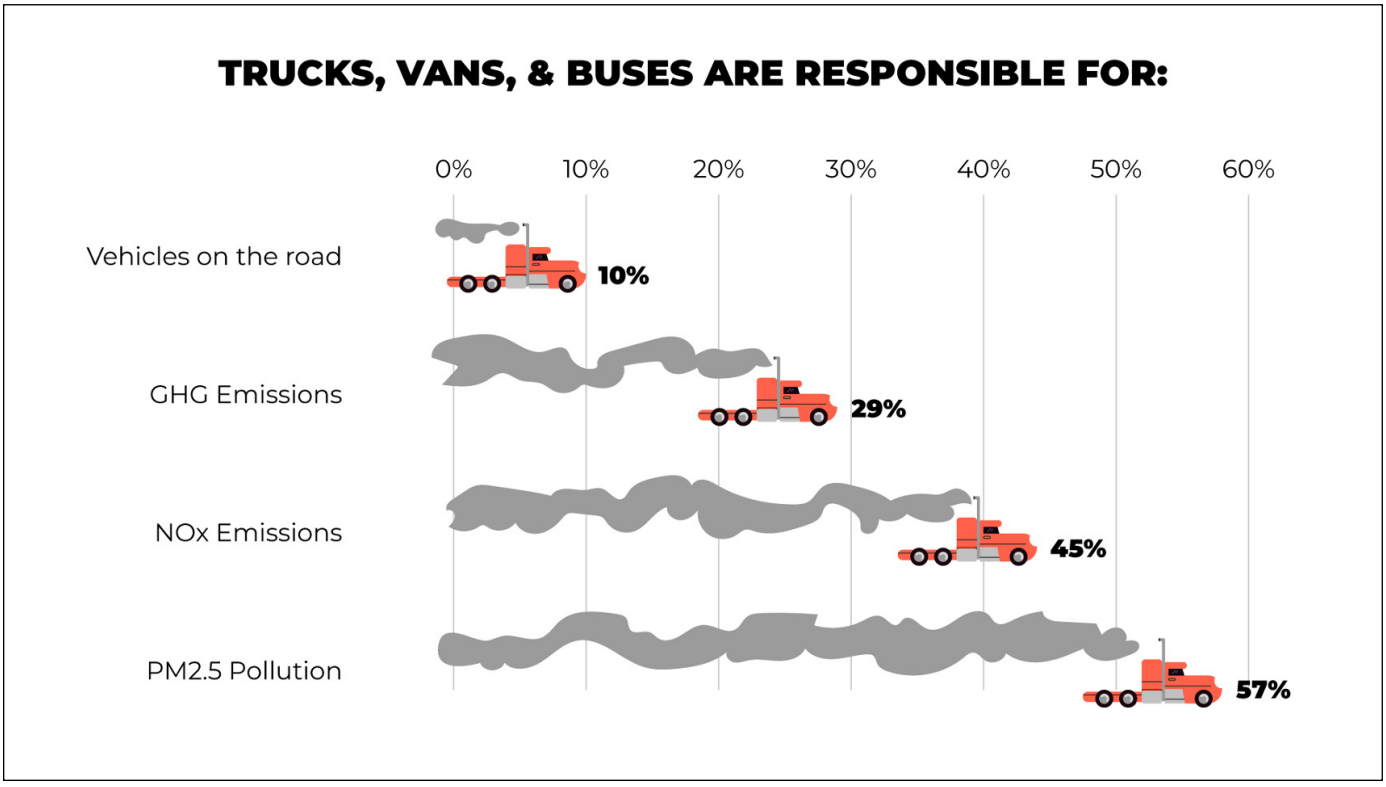
The trucking industry connects producers, suppliers, and consumers, making it an indispensable cornerstone of modern American society. Though the U.S. trucking industry has dramatically reduced its environmental and public health impacts in recent decades, it remains a major source of pollution, contributing to climate change and poor air quality, especially in the communities where these vehicles operate (Roeth, 2020).

WHY ZETS?

The transportation sector is responsible for the largest portion of greenhouse gas (GHG) emissions in the United States, generating roughly 28 percent of total GHG emissions (EPA, 2023). A significant portion of these emissions can be attributed to the trucking industry, which plays a vital role in the U.S. economy; however, its critical high-mileage haulage of the nation's freight emits significant amounts of GHGs and criteria pollutants, often in the most vulnerable communities.

While medium- and heavy-duty (MHD) vehicles represent only 10 percent of vehicles on the road, they are responsible for almost 30 percent of all transportation-related GHG emissions, 45 percent of nitrogen oxide (NOx) emissions, and more than half of fine particulate matter (PM2.5) emissions for all vehicles (Figure 2). Therefore, freight vehicles represent an outsized opportunity to reduce transportation-related emissions.

Figure 2. MHD Vehicle Share of Transportation Emissions (C40, 2023)



Transitioning to zero-emission trucks (ZETs) can substantially reduce harmful environmental impacts from the trucking industry, help to mitigate the effects of climate change, and protect public health. Emissions from freight vehicles also disproportionally affect the most vulnerable communities, as air quality is often worst near highways, warehouses, and ports—areas that tend to have more low-income communities and communities of color (EPA, 2023a). In sum, the transition to ZETs is needed to address environmental challenges and promote a more sustainable and healthier future for all.

WHAT ARE ZETS?

ZETs are a transformative category of commercial vehicles that emit zero tailpipe emissions (of carbon dioxide and criteria pollutants) and therefore reduce their environmental impact during use. These trucks utilize advanced technologies and alternative power sources to eliminate or significantly reduce the release of pollutants into the environment.

There are currently two technology types of ZETs readily available: battery-electric trucks (BETs), fueled with electricity, and fuel cell electric vehicles (FCEVs), fueled with hydrogen. While both use electricity to propel the vehicle, BETs store their electricity in battery packs and FCEVs store hydrogen in high-pressure tanks that, when combined with oxygen from the air in fuel cell stacks, produce electricity. Some consider FCEVs to be a "range extended" version of BETs since both have batteries, though FCEVs typically have much smaller battery packs. This report does not consider "low-emission" or "near-zero-emission" vehicles like natural gas (compressed, liquid, or renewable), hybrid electric, hydrogen internal combustion, renewable diesel, or biodiesel to be ZETs.

ZET technology offers a promising solution for decarbonizing the commercial transportation sector. Though the range of early generation BET models was limited to 100 or less miles on a single charge, thanks to increased energy density and declining battery prices, many of today's models boast ranges exceeding 300 miles, with some able to travel up to 500 miles before needing to refuel (CALSTART, 2022). These ranges can be further extended with electrified trailers and/or maximized regenerative braking. En-route charging mid-shift or between shifts can also allow vehicles to travel many more miles per day than they would otherwise be able to accommodate on a single charge. The majority of freight routes for MHD vehicles are well within these ranges, with approximately 67–87 percent of U.S. freight travelling in shipments less than 250 miles (Geotab, 2021; DOE, 2023).

Options are in development for long-haul trucking as well. Although there are not yet commercially available ZETs with sleeper cabs, FCEVs are coming to market with ranges up to 500 miles and BET technology continues to improve over time. Faster, smarter, and higher-power charging solutions and standards are also in development, enabling trucks to recharge in a timeframe close to parity with diesel refueling (CharIN, n.d.).

While the batteries and fuel cell tanks do add additional weight to the trucks—potentially limiting the payload a vehicle can carry—this impacts a relatively small segment of the trucking industry, as most trucks are constrained by volume more so than weight. In fact, nearly nine in ten trucks on the road

operate below the 80,000-lbs. federal maximum weight (DOE, 2023a). Additionally, the Federal Highway Administration (FHWA) provides for a 2,000-lbs. weight exemption for BETs, allowing them to operate at up to 82,000 lbs. (FHWA, 2019).

While ZETs may not be feasible for every truck application today, it is evident that current models are generally sufficient to meet the needs of a majority of truck types and routes—and certainly to achieve the deployment levels required by existing policies. As the technology continues to develop, next-generation models are expected to meet the operational needs of remaining duty cycles.

U.S. COMMITMENT

Taking stock of the progress made by ZET technology, in November of 2022, the United States signed the Global Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles (Global MOU), committing to work with other signatory countries to enable 100 percent of new truck and bus sales to be zero-emission (ZE) by 2040, including an interim goal of 30 percent by 2030 (CALSTART, 2023). The Global MOU is co-led by CALSTART's Global Commercial Vehicle Drive to Zero program and campaign and the Government of The Netherlands, with the purpose of accelerating the growth of ZE commercial vehicle adoption. The Global MOU has been signed by a total of 33 nations and has been endorsed by more than 115 subnational governments, manufacturers, suppliers, and other industry stakeholders. The Global MOU symbolizes a commitment to work together to overcome strategic, political, and technical barriers to ZE commercial vehicle adoption. With an increase in investment and economies of scale, this transition can be faster, more cost-effective, and easier for all stakeholders.

The Global MOU has been signed by a total of 33 nations and has been endorsed by more than 115 subnational governments, manufacturers, suppliers, and other industry stakeholders.

In line with the Global MOU, the U.S. National Blueprint for Transportation Decarbonization emphasizes the need to transition to zero-emission vehicles (ZEVs) to meet the country's GHG reduction goals, including for MHD vehicles (DOE, 2023b). Data in this report track progress with respect to the U.S. truck fleet.

CHAPTER II

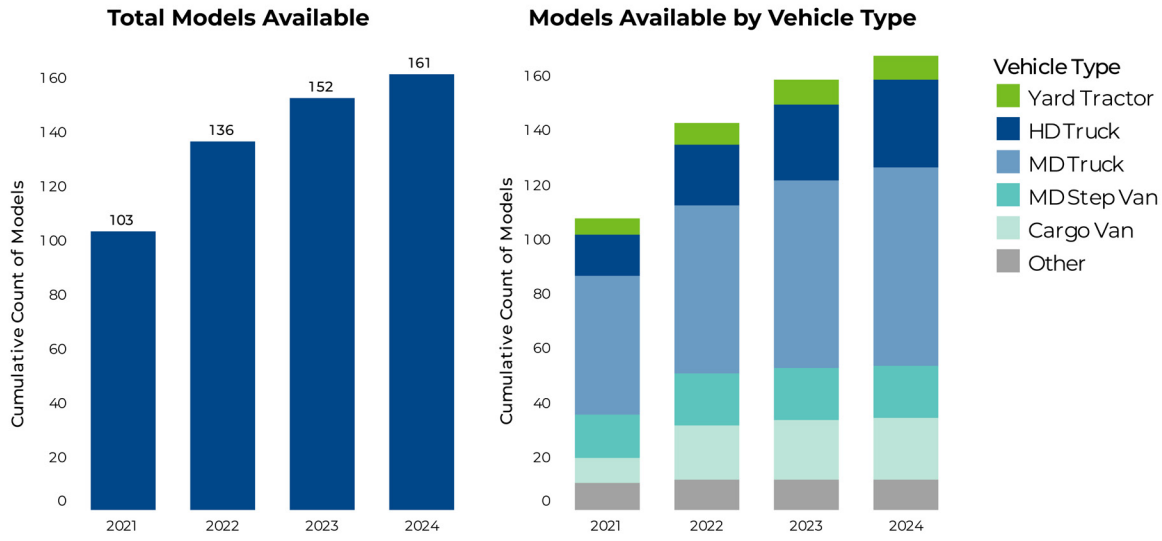
U.S. ZET MARKET UPDATE

ZET MODEL AVAILABILITY

The growth in ZET offerings has expanded each year and can be attributed to many technological advancements, original equipment manufacturer (OEM) investment, increased regulatory action, and nationally and organization-based climate goals. In 2019, only a couple dozen ZET models were available in the United States; there are now more than 160 models available.[7] And while ZET models were once dominated by retrofitters, today more than 40 OEMs have at least one ZET offering, including all the major legacy manufacturers. Numerous startups are also contributing to the advancement of ZETs.

The ZE MD truck market has the most options with 73 models available, followed by ZE HD trucks with 32 models and ZE cargo vans with 23 models (Figure 3). This is fitting given that these vehicle segments are the three largest in terms of current vehicle stock on the road.

Figure 3. ZET Model Availability Over Time (CALSTART, 2023b)



7 The Zero-Emission Technology Inventory (ZETI) Data Explorer includes current and future ZET models that have been announced.

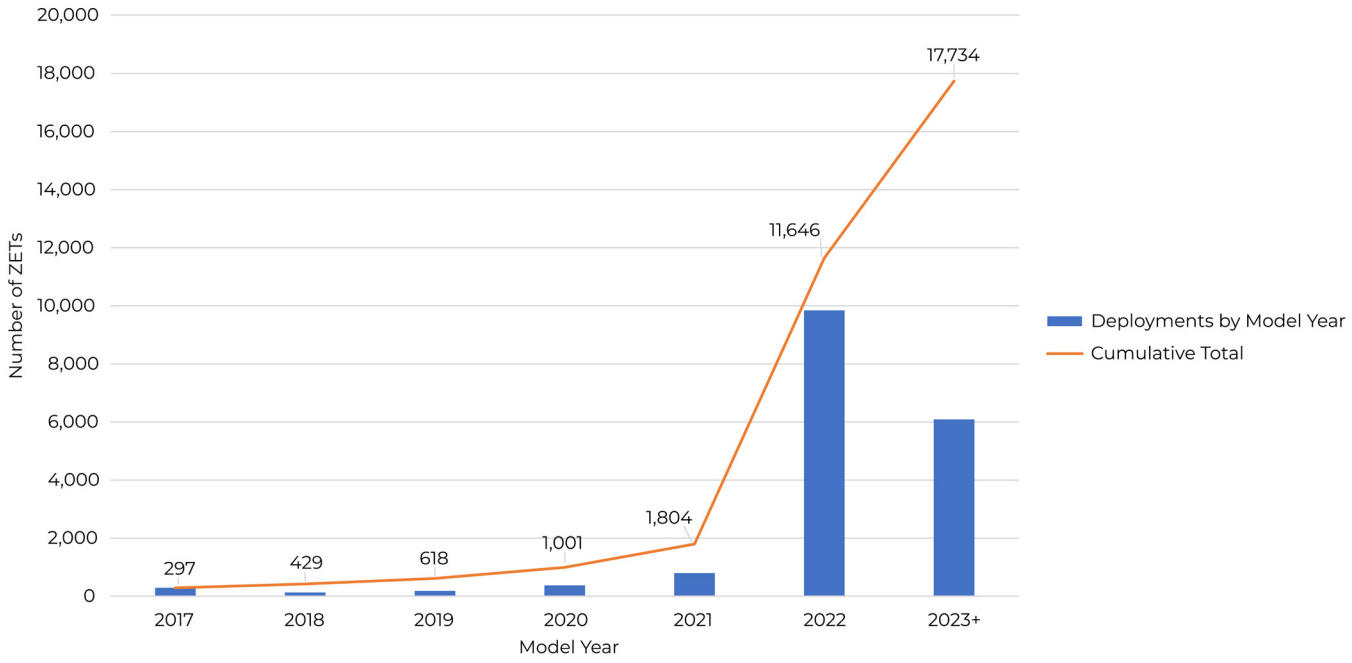
As expected, the number of new ZET models coming to market has tapered off in 2023 due to the significant progress made from 2019 to 2022. Many OEMs are now focused on increasing sales of existing models while also refining their initial ZET offerings based on real-world customer experience and feedback and developing second- or third-generation versions.

Most of the available ZET models fall under the battery-electric technology type. However, FCEV models are starting to see significant growth in availability. In 2021, four FCEV models were available, and as of this writing, there are 12 models available, mainly in the HD truck segment. FCEV model availability is expected to increase in the coming years as many OEMs are currently developing FCEV options (see *Hydrogen Fuel Cell Developments* section).

TOTAL ZET DEPLOYMENTS

As of June 2023, more than 17,500 ZETs have been deployed in the United States,[8] more than doubling the number of total deployments reported in the previous *Zeroing in on Zero-Emission Trucks: May 2023 Market Update*. Figure 4 outlines the distribution of ZET deployments by vehicle model year along with the cumulative total year-over-year, and Table 1 breaks down ZET deployments by vehicle segment and model year.

Figure 4. U.S. ZET Deployments by Vehicle Model Year (2017–June 2023)



ZETs are defined as Class 2b-8 commercial vehicles, including cargo vans, MD step vans, MD trucks, HD trucks, refuse trucks, and yard tractors.

Data Source: CALSTART research

8 Trucks are defined as "deployed" if they have been delivered to the customer and registered with the Department of Motor Vehicles. Deployed truck counts do not include undelivered sales or fleet commitments for purchases. Past reports have referred to this as "deployed sales."

Table 1. U.S. ZET Deployments by Vehicle Segment and Model Year (2017-June 2023)

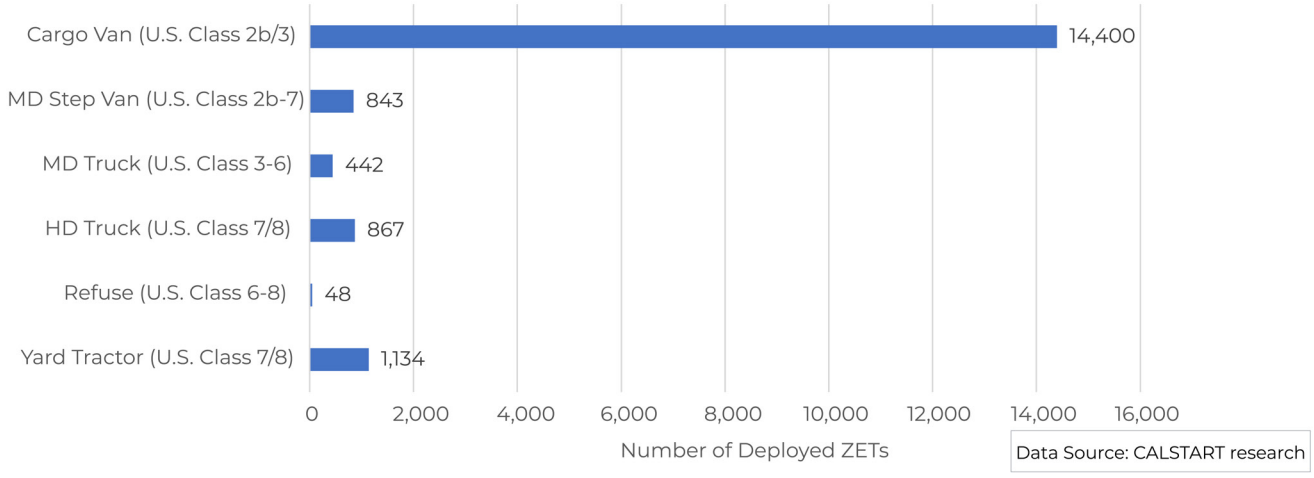
Vehicle Segment	2017	2018	2019	2020	2021	2022	2023+
Cargo Van	30	8	17	5	52	8,991	5,297
MD Step Van	223	25	21	14	275	238	47
MD Truck	18	57	12	44	124	98	89
HD Truck	8	0	16	93	90	219	441
Refuse	1	0	1	4	12	19	11
Yard Tractor[9]	17	42	122	223	250	277	203
Total	**297**	**132**	**189**	**383**	**803**	**9,842**	**6,088**

The continued significant increase in deployments can be attributed to a multitude of factors, including increased incentives, confidence in the technology, model availability, production capacity, and ZET policy adoption.

DEPLOYMENTS BY SEGMENT

The driving force behind such a dramatic increase in ZET deployments has been the meteoric rise of ZE cargo van deployments. Approximately 14,400 ZE cargo vans have now been deployed in the United States (Figure 5), which means 11,835 of these vehicles were deployed in the first half of 2023—a 461-percent increase in deployments from the previous report. Following cargo vans with respect to total ZET deployments are yard tractors (1,134), HD trucks (867), MD step vans (843), MD trucks (442), and lastly, refuse trucks (48).

Figure 5. Cumulative U.S. ZET Deployments by Vehicle Segment (2017–June 2023)



9 Yard tractor deployments are likely underreported as many are not registered for on-road use and much of the data on deployments come from vehicle registrations.

ZE cargo vans have been deployed more than other segments due to various factors, including smaller batteries, high production volumes (and marketing campaigns) from multiple OEMs, ideal duty-cycle capability, and much lower upfront costs compared to other vehicle segments. These factors have allowed several large companies to deploy ZE cargo vans throughout the country relatively quickly. The Commercial Clean Vehicle Credit also provides up to $7,500 toward the purchase price for ZE cargo vans,[10] which brings the price down to be cost competitive with combustion-powered cargo vans (IRS, 2023).

There have been steady increases in ZET deployment numbers among every other segment, though ZE HD trucks stand out as the only other segment that saw its first half of 2023 deployment numbers more than double its total deployments from the previous report, boasting a 250-percent increase. HD trucks are the most common among the vehicle segments, with more than 5 million total trucks registered in the country. The vast number of HD trucks on the road, combined with their high mileage, relatively low efficiency, and therefore high fuel burn, have made them a focal point for decarbonization, especially given the disproportionate amount of GHG and criteria pollutant emissions from these vehicles.

Since charging infrastructure is still in the process of being planned and built out along key freight corridors to support the electrification of long-haul trucks, ZE HD trucks have primarily been deployed in urban/regional or drayage duty cycles. While a number of states now have ZE HD trucks operating within their borders, California continues to lead in ZE HD truck deployments due to ambitious targets, initiatives, and incentives that support reducing emissions from this critical vehicle segment.

10 The Commercial Clean Vehicle Credit allows for up to $7,500 and $40,000 off the initial purchase price for Class 2b–3 and Class 4–8 commercial vehicles, respectively.

California Prioritizes Funding for HD Drayage Trucks

A driver in a heavy-duty fuel cell electric truck at California's Port of Oakland. Photo Credit: Harbor Trucking Association and Marc Harris Photography

In 2020, California Governor Gavin Newsom issued an Executive Order (N-79-20) that set a goal that all MHD vehicles in the state would be ZE by 2045 for "all operations where feasible" but specified an accelerated timeline for drayage trucks, requiring them to transition by 2035 (State of California, 2020). To realize this goal, the California Air Resources Board (CARB) launched Project 800, an initiative to support 800 ZE drayage truck orders to jumpstart the sector and pave the way for more ZETs serving California ports in the near future (CARB, 2021).

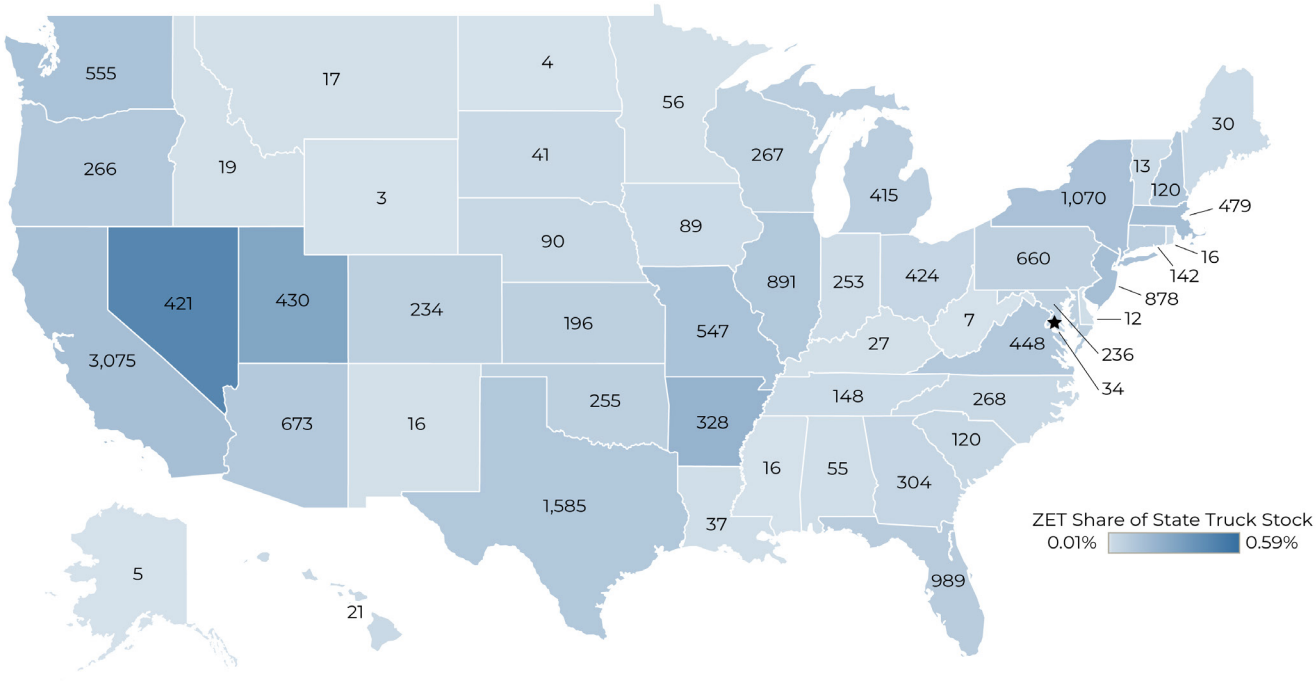
CARB also created special set-asides for drayage trucks within its Clean Truck and Bus Voucher Incentive Project (HVIP). More than 40 HVIP drayage vouchers have already been redeemed—with trucks now in operation—and hundreds more are in process. Additional funding for drayage trucks is available through the Port Plus Up, funded by the Port of Los Angeles and the Port of Long Beach (HVIP, 2023). Combined, these incentives can cover more than $400,000 toward the cost of a drayage truck.

Meanwhile, the California Energy Commission (CEC) has funding set aside through its Energy Infrastructure Incentives for Zero-Emission (EnergIIZE) Commercial Vehicles Project to support charging and hydrogen refueling infrastructure for ZE drayage trucks (EnergIIZE, 2023). With this statewide collaboration, financial support, and policies like the Advanced Clean Fleets (ACF) rule, California is expected to continue to lead the nation in ZE HD truck deployments in the years to come.

DEPLOYMENTS BY STATE

Tracking ZET deployments by state (Figure 6) can provide key insights to understand what conditions may best influence market growth. For example, a range of factors including policy mandates, incentive programs, utility make-ready programs, and electricity prices compared to diesel may all factor into a fleet's decision on if and where to deploy ZETs. Even proximity to OEM manufacturing facilities may sometimes impact ZET deployment locations.

Figure 6. Cumulative U.S. MHD ZET Deployments by State (2017–June 2023)



Represents only ZET deployments where the location is known. Some deployment numbers may differ slightly from previous reports due to corrections in data provided by OEMs. The number shown in each state is the number of ZETs in the state.

Data Source: CALSTART research

California continues to lead the nation with respect to ZET deployments, with approximately 3,075 ZETs deployed to date, though it now accounts for less than one-fifth of total U.S. ZET deployments. This is a testament to the viability of ZETs to perform in a wide range of climates and applications, and to the momentum being built to transition MHD vehicles to ZE across the country.

The top states for overall ZET deployments after California include Texas, New York, Florida, and Illinois. However, leading states differ by vehicle segment:

- ZE cargo vans from seven OEMs have primarily been deployed in Texas (1,498), California (1,494),

and Florida (953).

- ZE MD step vans from five OEMs have been deployed the most in California (320), New Hampshire (94), and North Carolina (63).
- ZE MD trucks from 12 OEMs have primarily been deployed in California (227), Iowa (38), and New York (25).
- ZE HD trucks from 12 OEMs have been deployed the most in California (346), Wisconsin (93), and New Jersey (91).
- ZE refuse trucks from four OEMs have primarily been deployed in Pennsylvania (10), California (7), Florida (5), and New Jersey (5).
- ZE yard tractors from three OEMs have been deployed the most in California (681), New York (55), New Jersey (39), and Colorado (39).

Note that much of the data used for this report are based on private correspondence with OEMs and vehicle registration data.[11] However, vehicles may not operate exclusively in the state in which they are registered.

OVERALL TRUCK MARKET

The U.S. truck market consists of more than 12 million Class 2b–8 trucks registered as of June 2023.[12] This truck stock is dominated by three segments, with HD trucks being the most common, accounting for roughly 5.1 million vehicles. HD truck registrations are followed by cargo vans and MD trucks, with approximately 3.7 and 3.6 million vehicles, respectively. These three segments combined make up roughly 97 percent of all truck registrations in the United States (excluding pickups).

This market segmentation is generally true of recent deployments as well, as these three segments accounted for 95 percent of model year 2022 deployments. However, more 2022 MD trucks were deployed (roughly 187,000) than HD trucks (roughly 185,000). Truck deployments are cyclical and can vary dramatically from one year to the next (Roeth, 2020a). For example, 2022 deployments were impacted by supply chain challenges, and the increased demand for MD trucks may be due in part to the professional driver shortage—one of the top four issues facing the trucking industry (The American Transportation Research Institute, 2023). As fleets attempt to hire drivers, some are increasingly open to those without commercial driver's licenses (CDLs), which represent a larger candidate pool because of the reduced training required. These non-CDL drivers are not certified to operate HD trucks but can still haul freight using MD trucks.

11 All data sources used to track ZET deployments are outlined in Appendix D.

12 As stated above, this analysis includes Class 2b–8 trucks, excluding pickup trucks.

Figure 7 illustrates the total truck stock and model year 2022 deployments as of June 2023 by vehicle segment.

Figure 7. U.S. MHD Truck Total Stock and Model Year 2022 Deployments by Vehicle Segment (Thousands)

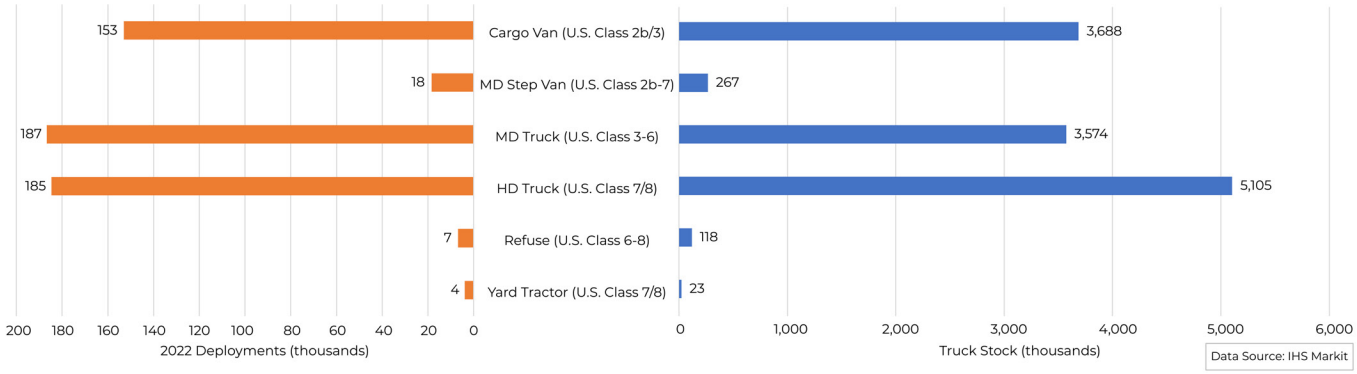
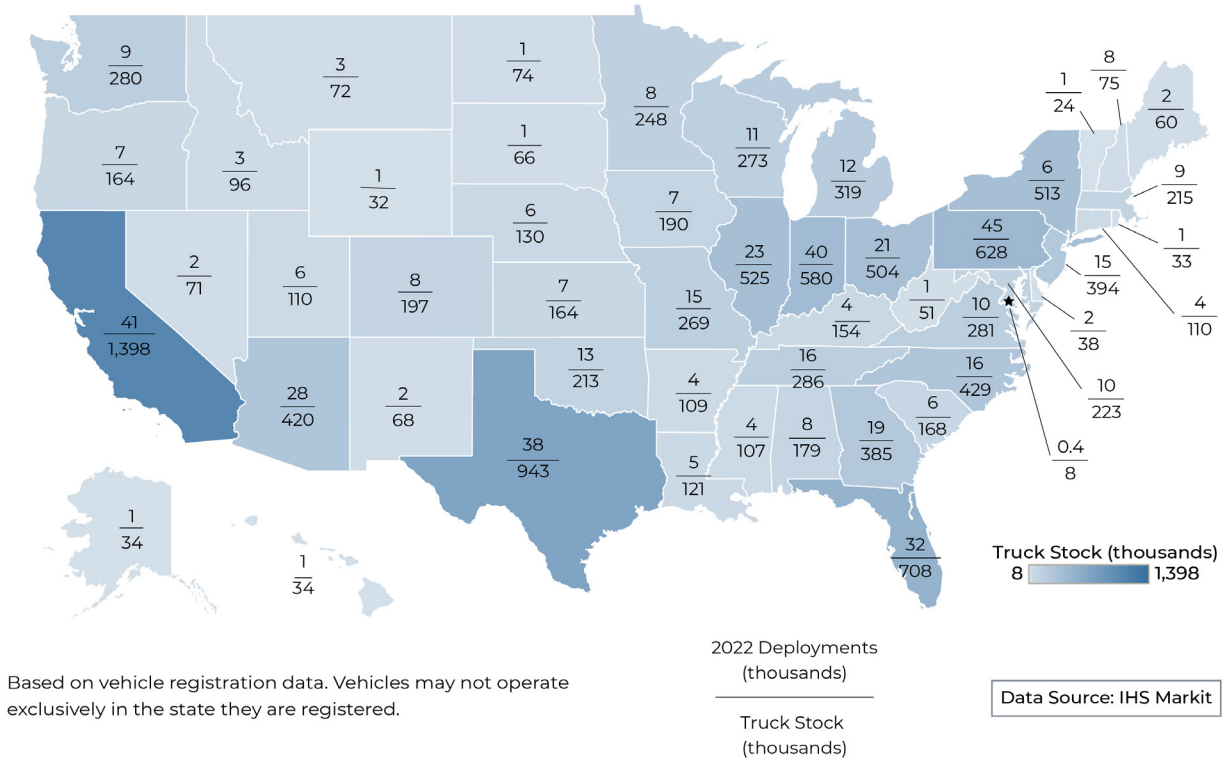


Figure 8 shows the total U.S. truck stock and model year 2022 deployments in thousands by state.

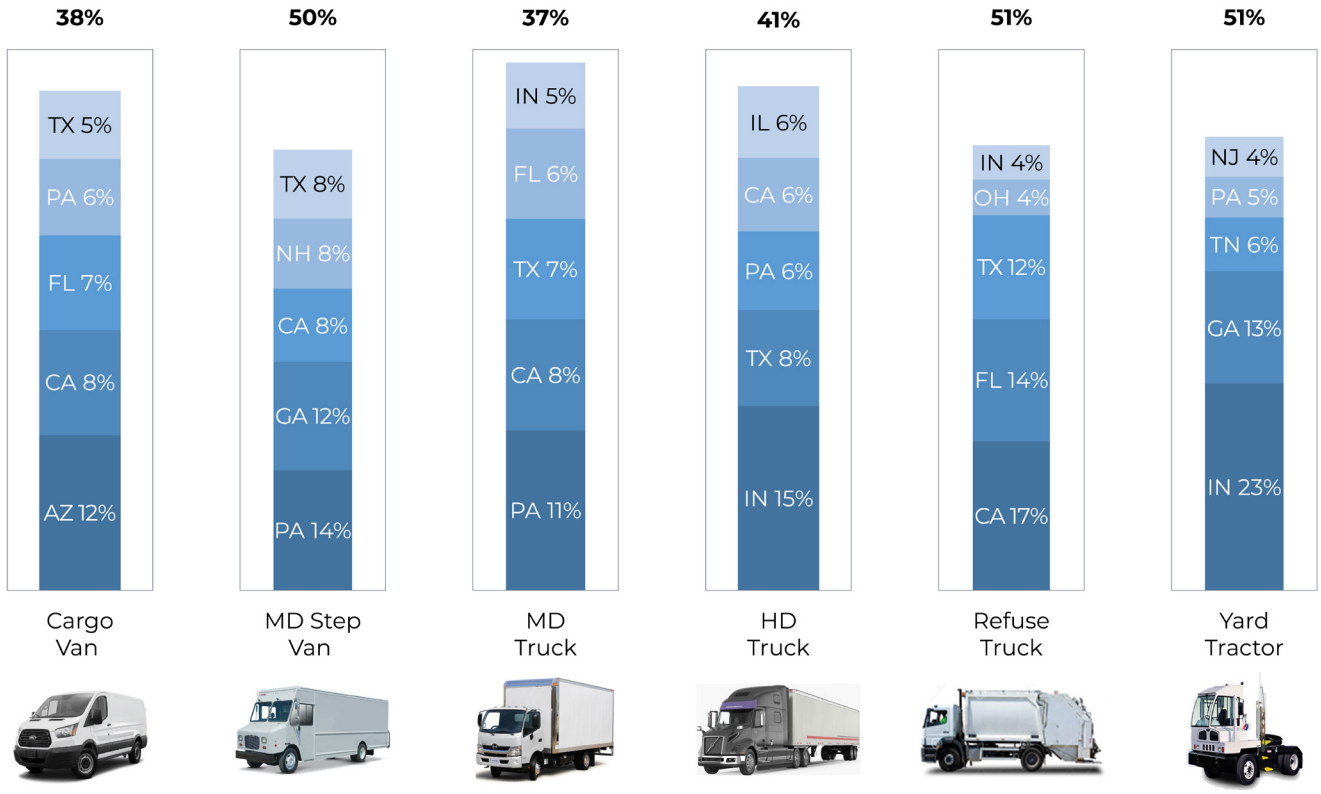
Figure 8. U.S. Truck Stock and Model Year 2022 Deployments by State (Thousands)



The largest truck populations can be found in California (10.9 percent of total U.S. stock), Texas (7.4 percent), and Florida (5.5 percent). However, these are not necessarily the largest markets for new deployments. Rather, 2022 truck deployments were greatest in Pennsylvania (8.1 percent), California (7.3 percent), and Indiana (7.1 percent).

Similar to the ZET market, top states for overall truck deployments differ by vehicle segment. Figure 9 displays the five leading states for 2022 deployments by vehicle segment. For each segment, the top five states make up more than one-third of the total deployments, and in some cases more than half of the total deployments: cargo van (38 percent), MD step van (50 percent), MD truck (37 percent), HD truck (41 percent), refuse truck (51 percent), and yard tractor (51 percent).

Figure 9. Top Five U.S. States for Model Year 2022 Truck Deployments by Vehicle Segment



Number atop each bar is total percentage of listed states.

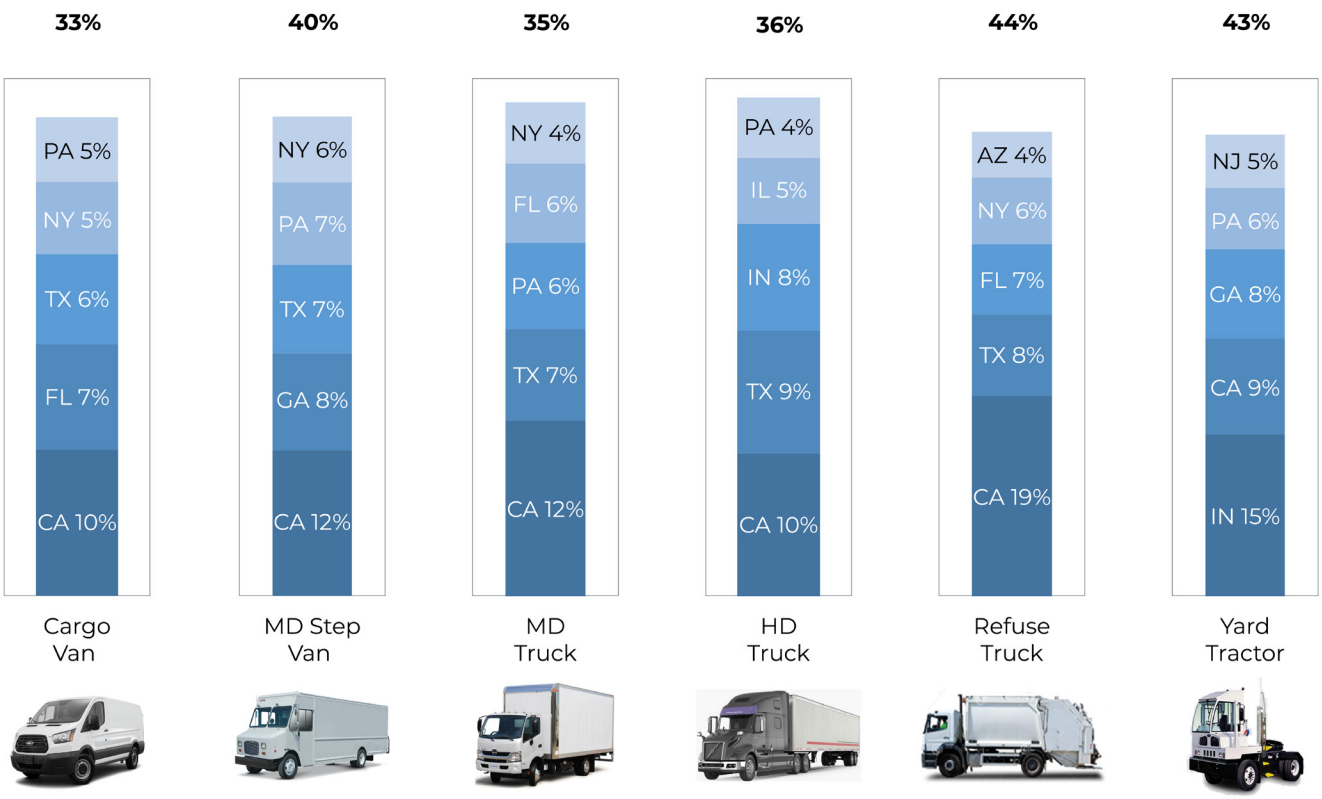
Data Source: IHS Markit

The distribution of deployments by vehicle segment has seen little change over the past six months. Most new deployments continue to be concentrated around freight hubs like Indiana, California, Georgia, Texas, and Pennsylvania, as all five states are well represented in 2022 deployments across all vehicle segments.

The distribution is similar when overall truck stock is considered by state and by segment. Figure 10 shows the five leading states for overall truck stock by vehicle segment. Like deployments, the top five states

represent more than one-third of the total registrations for each truck segment: cargo van (33 percent), MD step van (40 percent), MD truck (35 percent), HD truck (36 percent), refuse truck (44 percent), and yard tractor (43 percent).

Figure 10. Top Five U.S. States for Truck Stock by Vehicle Segment



Number atop each bar is total percentage of listed states.

Data Source: IHS Markit

Where certain vehicle segments tend to be registered has not changed significantly in the past few years. California continues to lead across all vehicle segments, except for yard tractors. California leads in overall truck stock with 10.9 percent of the market.

CHAPTER III

THE ROAD AHEAD

Rapidly accelerating the adoption of ZETs is necessary to reduce pollution from the trucking industry, improve public health, and mitigate climate change. An understanding of the current market and the tactics that have worked to deploy ZETs can provide insight on how to build off early successes.

OBSERVED MARKET TRENDS

Ten key market trends are currently driving ZET deployments (Figure 11).

Figure 11. Observed 2023 U.S. ZET Market Trends

INCREASED AND MATURED MODEL AVAILABILITY

The noticeable increase in ZET adoption since the previous version of this report is due in part to the increased availability of models from all OEMs. As Figure 3 showed earlier, there are now more than 160 ZET models available in the United States from more than 40 OEMs. With these increasingly diverse market offerings, fleets have never had more options capable of meeting their operational needs. This increased competition—along with increasing production volumes and decreasing battery prices—is expected to bring ZET prices down over time, as has been observed in the passenger car market (Dnistran, 2023).

Increased model availability is due in part to the emissions reduction commitments of many truck manufacturers, including legacy OEMs (Garcia Coyne et al., 2021). Table 2 outlines the major OEMs that have set forth a U.S. ZEV or carbon neutrality goal as of December 2023.[13] These goals, coupled with the influx of exclusively ZE companies, have spurred ZET model availability to an all-time high.

Table 2. OEM Commitments to U.S. ZEV Sales and Carbon Neutrality

OEM	ZET Target	Target Year	Source
Cummins	Reduce Scope 3 absolute lifetime GHG emissions from newly sold products by 25%	2030	Cummins, n.d.
Daimler Trucks North America	All new trucks and buses will be carbon neutral	2039	Daimler Truck, n.d.
Ford	100% fossil-free new vehicle sales	2040	Foote, 2021
General Motors	Sell ZE version of all HD trucks	2035	Mihalascu, 2022
Hyundai	Carbon neutrality	2045	Hyundai, 2021
Isuzu	Zero GHG emissions arising directly from Isuzu Group operations	2050	Isuzu, n.d.
Navistar	100% new vehicle sales to be ZE	2040	Navistar, n.d.
PACCAR	Net-zero GHG emissions	2050	Climate Action 100, 2023
Volvo Group	100% fossil-free product sales	2040	Volvo Group, 2023

13 Table 2 does not include ZE-only manufacturers as their targets are inherently ZE.

Increased model availability and production volumes allow these OEMs to grow their ZET business, enabling them to achieve their goals while meeting regulatory requirements.

EXPANSION OF REGULATIONS TO ADDITIONAL GEOGRAPHIES

The Unites States' commitment to decarbonize the trucking industry can be seen through the many regulations being put into place at both the federal and state levels. For example, in 2023, at the federal level, the U.S. Environmental Protection Agency (EPA) announced a proposal for more stringent standards to reduce GHG emissions from trucks. The proposed Phase 3 standards would reduce carbon dioxide emissions by approximately 1.8 billion metric tons from 2027 to 2035 and would provide significant climate and health benefits (EPA, 2023b). The EPA rule is expected to be finalized in early 2024.

Meanwhile, the most stringent policies regarding ZET deployments have been passed at the state level. For example, the Advanced Clean Trucks (ACT) rule requires truck manufacturers to sell an increasing number of ZETs as a percentage of their overall truck sales. First passed in California, seven additional states[14] had adopted ACT as of June 2023.[15] Though model year 2024 trucks are the first to be subject to the rule, the industry is already experiencing the effects of ACT, the anticipation of which has spurred more robust supply chains and increased production volumes. Though the eight ACT states combined represent approximately one in four trucks in the United States, they account for nearly 40 percent of ZET deployments through June 2023.

Many additional states are considering adoption of the ACT rule. Seventeen states plus the District of Columbia signed the Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding (MOU), agreeing to strive to make all sales of new MHD vehicles in their jurisdictions be ZE by 2050 (NESCAUM, 2022). The MOU also includes an interim goal of 30 percent ZE sales by 2030 and commits the states to consider adoption of ACT.

In April 2023, California also adopted the Advanced Clean Fleets (ACF) rule, requiring large fleets with operations in California to deploy an increasing number of ZETs as a proportion of their overall fleet. It also requires any new drayage trucks to be ZE. ACF complements ACT by ensuring customer demand for ZETs is there to match the increased supply from OEMs. ACF also includes a provision to cease the sale of combustion trucks entirely, necessitating all MHD vehicle sales be ZE by 2036 (CARB, 2023). ACT and ACF work in tandem to send a clear market signal to both truck manufacturers and purchasers.

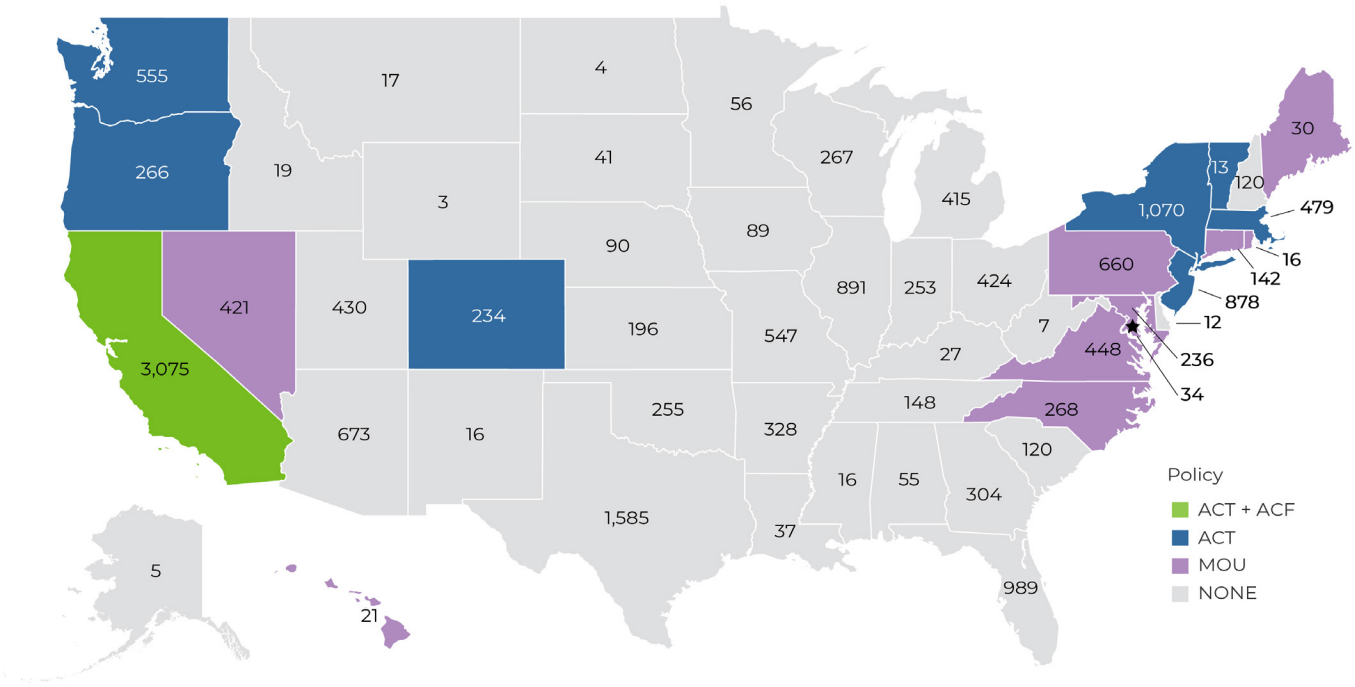
Taken together with local policies regulating emissions from warehouses and requiring streamlined permitting of electric vehicle charging, these regulations have without a doubt resulted in increased ZET deployments in leading geographies (South Coast Air Quality Management District, n.d.; GO-Biz, n.d.). Figure 12 presents the number of ZETs deployed by state (where the state can be identified) and shows

14 Other states that have adopted the ACT regulation as of June 2023 include Colorado, Massachusetts, New Jersey, New York, Oregon, Vermont, and Washington. New Mexico, Maryland, and Rhode Island adopted ACT later in 2023, after the data cutoff for this analysis.

15 Per its authority under section 209 of the Clean Air Act (CAA), California can set more stringent emissions standards than the federal government. Under Section 177 of CAA, other states can then adopt California's standards.

each state's policy status as of June 2023. The policy levels shown are states that have adopted both the ACT and ACF rules (green), states that have adopted only the ACT rule (blue), states that have adopted neither but have signed the MOU indicating intent to adopt the ACT rule (purple), and non-MOU states (gray).

Figure 12. State ZET Deployments and Policy Status (2017–June 2023)



Represents only ZET deployments where the location is known. Some deployment numbers may differ slightly from previous reports due to corrections in data provided by OEMs.

Data Source: CALSTART research

California has announced that it hit its goal of 6 percent of new trucks sold in the state being ZE by 2024 two years early, exceeding the original goal in 2022 with 7.5 percent of trucks sold (including light-duty trucks) being ZE (Office of Governor Gavin Newsom, 2023).

HISTORIC LEVELS OF FUNDING AVAILABLE

Regulations are most likely to be successful when paired with a full ecosystem of supportive programs, including incentives. Though the total cost of ownership (TCO) of a ZET may already be lower than that of a combustion truck (due to the increased efficiency of ZE powertrains and lower operational costs from less maintenance and lower fuel costs), this is not yet true across all duty cycles (though ZETs are expected to achieve TCO parity by the end of the decade, across all standard duty cycles) (Argonne National Laboratory, 2023; Hunter et al., 2021). Even with the promise of lower TCO on the horizon,

incremental purchase price—as well as the costs to install charging, upskill employees, and purchase insurance for these more costly vehicles—remains a barrier to ZET adoption for many fleets.

Fortunately, historic levels of funding are available to help U.S. fleets overcome the upfront price premium and deploy ZETs. Analysts estimate approximately $32 billion will be available on average per year for the next few years (Gladstein, Neandross, & Associates, 2023). This support represents an order of magnitude in growth from estimates just two years prior, highlighting the rapid increase in funding availability and overall momentum in the industry.

Similar to policy, this funding is a combination of state and federal programs. ZETs can cost upwards of two to three times the price of a similar combustion truck, so incentives that help lessen this upfront cost premium help make ZE technology more accessible for fleets. At the federal level, the Inflation Reduction Act (IRA)-authorized Commercial Clean Vehicle Credit helps cover the incremental cost of ZETs by providing a credit of up to $40,000 per truck (IRS, 2023). This credit, combined with the Alternative Fuel Refueling Infrastructure Credit, is expected to help ZETs achieve TCO parity with combustion-powered trucks approximately five years sooner than without IRA (Kahn et al., 2022).

At the state level, voucher incentive programs act as a tool to support ZET deployments by offering cash-on-hood funding toward a ZET at the time of purchase. States that offer upfront vehicle incentives, such as California, New York, and New Jersey, have seen greater adoption of ZETs across all vehicle segments. States with a statewide ZE MHD vehicle incentive program prior to 2023 make up 39 percent of all ZET deployments.[16] Some state-level incentive programs also offer funding for charging or refueling infrastructure. To date, there are 15 MHD vehicle incentive programs across 10 states. Additional states are able to take advantage of available federal programs to fund new ZET voucher programs (Mandel et al., 2023). See Appendix A for a list of known ZET incentive programs in the United States.

Additional funding to support ZET deployments is increasingly available from utilities and local government as well (Office of Energy Efficiency and Renewable Energy, n.d.). For example, numerous electric utilities offer "make-ready" programs that can cover the cost of electrical grid upgrades necessary to make the distribution system and/or charging site (i.e., fleet depot) capable of charging ZETs. These make-ready programs are approved by state public utility commissions and funded by ratepayers. Research based on real-world data shows that these programs can drive down electric rates over time for all electricity customers in a utility's territory due to the increased sales of electricity that these programs enable (Whited et al., 2023; MacDougall, 2023). See Appendix B for a list of known utility make-ready programs in the United States.

MORE ROBUST BATTERY SUPPLY CHAINS

For BETs, the battery comprises approximately 70 percent of the overall vehicle cost (Beaty, 2021). Because batteries represent such a large portion of overall vehicle cost, a decrease in their cost has an outsized impact on electric truck pricing. Therefore, another factor impacting overall cost and deployment

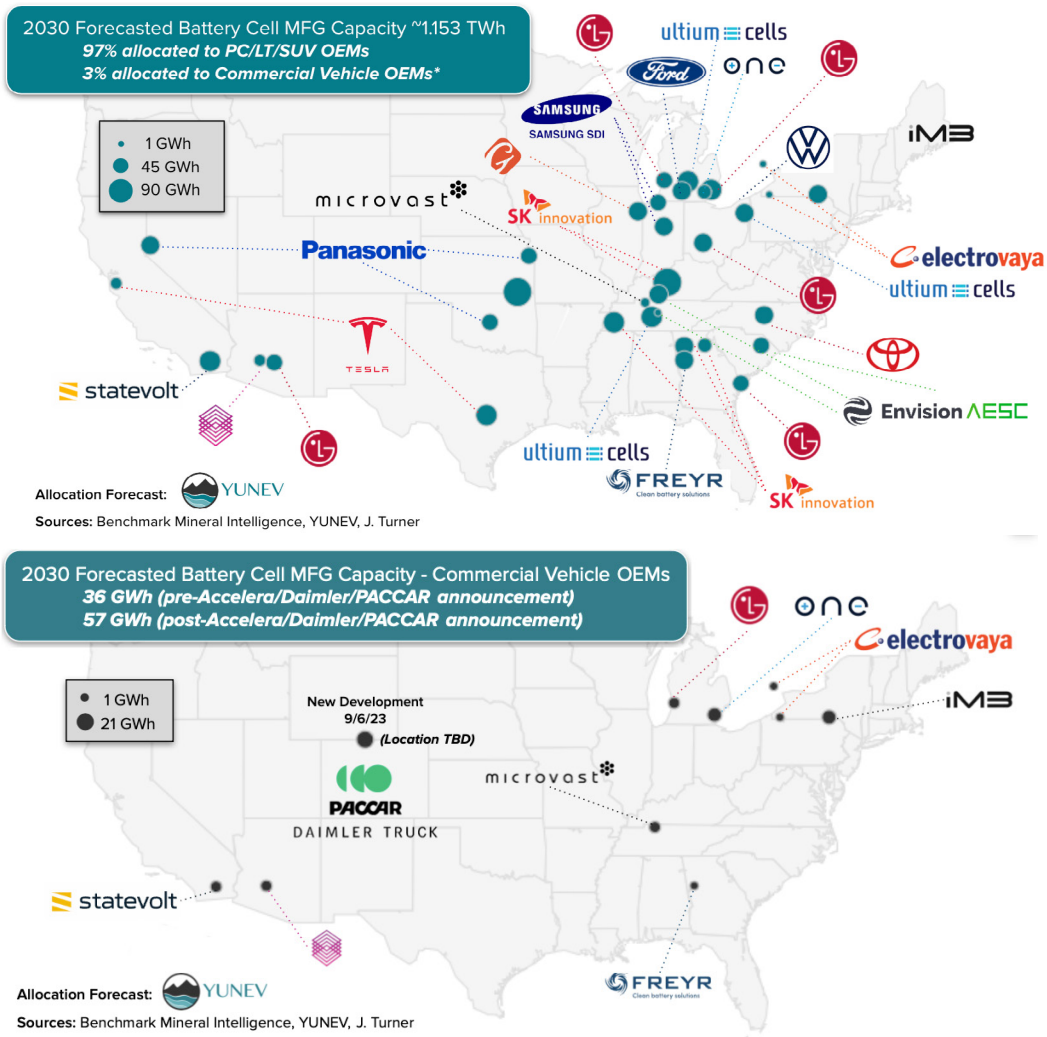
16 For more information about state incentive programs, see Appendix A.

feasibility for ZETs has been the declining cost of lithium-ion battery packs, which have reduced in price nearly 90 percent over the last 15 years (Vehicle Technologies Office, 2023). In just the last year, from 2022 to 2023, average lithium-ion battery pack prices fell 14 percent, due largely to declining raw material costs (Stoikou, 2023). Battery pack prices are expected to continue falling by an average of 11 percent per year from 2023 to 2030 (Goldman Sachs, 2023).

However, it is important to note that ZE commercial vehicles are not able to access batteries at passenger car prices, due in large part to lower production volumes and therefore higher and more volatile battery prices. For example, while global electric passenger car manufacturers reported an average battery pack price of $128 per kilowatt-hour (kWh) in 2023, the commercial vehicle sector (excluding China) saw prices 45 percent higher at around $186 per kWh (Stoikou, 2023).

The MHD commercial vehicle market represents approximately 10 percent of the U.S. vehicle market; however, as illustrated in Figure 13, only about 3 percent of the forecasted 1.2 terawatt-hour battery cell manufacturing capacity is allocated to the commercial vehicle sector.[17]

Figure 13. Maps of Overall and Commercial Vehicle Dedicated U.S. Battery Production Capacity



17 Battery capacity research, data, and infographic (Figure 13) provided by YUNEV.

This inequity is exacerbated by the fact that electric trucks require much larger battery packs than light-duty electric vehicles. Furthermore, the relatively small volumes of truck battery production are split by OEM market share and product differentiation. Some OEMs are realizing they need to partner up with competitors on batteries and fuel cell technologies to get pricing down.

Limited battery production not only has implications on vehicle cost but also impacts the number of ZETs that OEMs are able to produce. For example, GM had to temporarily shut down production of its all-electric BrightDrop delivery vans this past fall due to difficulties securing batteries (Noble, 2023). Production is expected to resume in Spring 2024 when GM opens a new battery-module line. Similarly, Romeo Power, which was bought by Nikola and then liquidated in less than a year, also negatively impacted OEM customer production volumes.

As they look to scale production and minimize price volatility, several other ZET OEMs have begun to make investments in commercial vehicle-focused battery manufacturing. For example, in September 2023, Accelera by Cummins, Daimler Truck, and PACCAR announced a joint venture to advance battery cell production in the United States (Daimler Truck, 2023). The planned joint venture will invest between $2–3 billion for a 21 gigawatt-hour factory. Two months later, the Volvo Group announced plans to purchase Proterra Powered, the bankrupt company's battery business unit, including a development center for battery modules and packs in California and an assembly factory in South Carolina (Volvo Group, 2023a).

IRA-funded subsidies for new U.S. battery manufacturing are available via the Advanced Manufacturing Production Credit (45X). These credits offer $35 per kWh of capacity for battery cells and $10 per kWh for battery packs or modules produced in the United States (McDaniel, 2023). These credits offer $35 per kWh of capacity for battery cells and $10 per kWh for battery packs or modules produced in the United States (McDaniel, 2023). These credits are expected to spur additional investments in domestic battery supply, though it will take a few years for the impacts of these investments to be felt by the industry. These developments are expected to create more than 102,000 U.S. jobs in battery manufacturing, spread across 31 states, with the highest concentration in the emerging Battery Belt (Olano, 2023). Projects spurred by IRA are expected to create an additional 38,000 U.S. jobs in electric vehicle manufacturing. In November 2023, the U.S. Department of Energy (DOE) also announced $3.5 billion for domestic battery manufacturing, prioritizing production and manufacturing for specialized, non-light-duty markets (DOE, 2023d). More investments are needed to expand and strengthen the domestic battery supply chain with dedicated battery manufacturing capacity for MHD vehicles.

IRA-funded subsidies for new U.S. battery manufacturing are available via the Advanced Manufacturing Production Credit (45X). These credits offer $35 per kWh of capacity for battery cells and $10 per kWh for battery packs or modules produced in the United States (McDaniel, 2023).

Meanwhile, fuel cell prices have been falling significantly over the past decade, with FCEVs experiencing a 65-percent reduction in prices (Pocard, 2012). As production volumes increase, cost is expected to continue to fall significantly (Deloitte and Ballard, n.d.).

UNPRECEDENTED INVESTMENTS IN CHARGING INFRASTRUCTURE

ZET deployments have also been spurred by historic investments in charging infrastructure. Many fleets have now installed charging at their depots to support truck electrification. Depending on the number of ZETs being deployed, their charging needs, and existing grid capacity at the site, this infrastructure can be put in place in as little as a few months. Sometimes, this buildout may take a few years, due largely to utility timelines and supply chain constraints. Policymakers, regulators, utilities, nonprofit organizations, and other stakeholders are working to identify opportunities to speed up this energization process.

To help bridge this temporary gap, fleets should consider solutions like the "3 M's"—mobile charging, managed charging, and microgrids—to support faster deployment of depot-based charging infrastructure. (Learn more in the *Accelerate Utility Processes* section below.)

Non-depot charging solutions are increasingly important as well. Shared and public charging solutions are critical for enabling many fleets to deploy ZETs, including those that:

- Do not have a depot at which they park the vehicle(s) overnight.
- Lease depots and whose landlords are unwilling to allow charging.
- Have depot charging but would like redundancy in case of downtime.
- Have depot charging but need en-route charging for longer routes.
- Cannot afford the capital expenditure for charging infrastructure.
- Do not have space/real estate at their depot for charging.
- Are planning to install depot charging but for whom permitting and/or energization will take longer than truck delivery timeline.
- Are considered over-the-road or long-haul.

Fortunately, these sorts of shared and public charging solutions are increasingly available. For example, Electric Island opened publicly accessible electric truck charging in 2021 in Portland, Oregon (Daimler Truck North America, 2021). The Port of Long Beach has offered free ZET charging since late 2022 (Port of Long Beach, 2022). Public ZET charging is also available at TruckNet's Otay Mesa location near the Port of San Diego, and the Los Angeles Cleantech Incubator (LACI) has funding and plans to open public truck charging at the Port of Los Angeles (Nikolewski, 2023; LACI, 2023).

Meanwhile, Charging-as-a-Service (CaaS) providers are opening shared charging sites. WattEV's depot near the Port of Long Beach opened in 2023, and the company has plans to open three more in California—Bakersfield, San Bernardino, and Gardena—in early 2024 (PR Newswire, 2023). WattEV has also received funding to open CaaS depots along I-5 in Sacramento, California, and Salem, Oregon (Hampel, 2023). CaaS company Forum Mobility has also opened its first charging depot for Hight Logistics and has plans to expand to serve many drayage fleets across California, with investments from CBRE, Amazon's Climate Pledge Fund, and Homecoming Capital to do so (Forum Mobility, 2023). Additional CaaS startups like Terawatt and Voltera also have ambitious plans to open charging depots to support electric trucks. And freight-forwarding companies are taking advantage of Zeem Solutions' "fleet-as-a-service" depot

at Los Angeles International Airport in Southern California, enabling them to deploy electric box trucks (FleetOwner, 2022).

A conceptual rendering of Forum Mobility's FM Harbor electric truck charging depot at the Port of Long Beach. Image Credit: Forum Mobility

ZET OEMs are also investing in public charging. For example, Volvo and Pilot Company have announced a partnership to deploy truck charging at select Pilot and Flying J travel centers, ideally positioned along transportation corridors (Pilot Company, 2022). Volvo has also partnered with Volvo Financial Services, Volvo Technology of America, Shell Recharge Solutions, TEC Equipment, Affinity Truck Center, and Western Truck Center to develop a publicly accessible ZET charging network that connects several of California's largest metropolitan areas (Volvo Trucks North America, 2022). Daimler Trucks North America has partnered with NextEra Energy Resources and BlackRock to launch Greenlane, a $650 million joint venture to design, develop, install, and operate a U.S. nationwide, high-performance ZE public charging and hydrogen fueling network for MHD battery-electric and hydrogen fuel cell vehicles (Daimler Truck North America, 2023). Tesla has applied for $97 million in subsidies to build charging infrastructure for its electric Semi trucks from Texas to California (Hampel, 2023a). Billions of dollars have already been invested in building out this charging infrastructure, which will continue to come online in the coming years.

INCREASED SUPPORT FOR SMALL FLEETS

As noted above, charging infrastructure to support ZETs is particularly critical for smaller fleets that may not have their own depots and/or access to capital to build out private charging. In fact, small fleets face more barriers to implement ZETs into their operations overall, as they have fewer resources—financial, staff, and informational—than larger fleets and may also lack the ability to adapt to technological issues (Dream.org, 2022).

Yet, small fleets are the norm in the trucking industry. According to the American Trucking Association, 95.8 percent of fleets operate 10 or fewer trucks and 99.7 percent operate 100 or fewer (American Trucking Association, 2023). To ensure the many small fleets and independent owner-operators in this country are not left behind in the transition to ZETs, governments have created special fleet assistance programs like Cal Fleet Advisor and Mass Fleet Advisor[18] to provide concierge-style technical assistance tailored to specific fleets' needs. Advisors in each program can assist fleets with education on vehicles, fueling, and regulations, as well as provide technical assistance with TCO analysis, duty-cycle analysis, and fueling strategies. These assistance programs allow fleets to have a go-to contact that can help guide them to the correct resources, such as utilities, dealers, OEMs, and incentive programs to ensure a fleet's success in the ZET transition. Some special incentives are available for small fleets as well. For example, California's Clean Truck and Bus Voucher Incentive Project (HVIP) offers larger voucher amounts for small fleets. It also has a special carve-out known as the Innovative Small e-Fleet (ISEF) program, which allows trucking fleets with fewer than 20 trucks to access flexible financing, lease, rental, and packaged Truck-as-a-Service (TaaS) options that include enhanced incentives and fueling support. First launched in 2022, ISEF was very popular, having its $25 million budget quickly oversubscribed. ISEF reopened in 2023 with a budget of $83 million (CARB, 2023b).

Similarly, industry is also experimenting with innovative business models to better support small fleets in transitioning to ZETs. For example, as-a-service models like TaaS or CaaS offer fleets the ease and flexibility of an all-in-one package that can include the vehicle, charging, and maintenance for a monthly subscription. This enables fleets to forgo the high upfront capital expenses and allows them to trial vehicles for their operations with shorter-term subscriptions capable of recognizing lower TCO as affordable operational expenses. These solutions are great ways to expand access to ZETs for fleets that may not have the upfront capital or internal expertise to otherwise make the transition. New York is piloting these innovative as-a-service business models via the Clean Transportation Prize state-funded Freight Electrification-as-a-Service for Transformation (FEaST) project (CALSTART, 2022).

Since many small fleets typically purchase used trucks rather than new ones, the industry is also exploring opportunities to promote a more robust used ZET market.

INCREASED PUSH FROM SHIPPERS

Whether small or large, fleets are increasingly transitioning to ZETs to realize ambitious sustainability goals. As investor, employee, and regulatory pressure mounts to address climate change, companies are committing to transparently report on and reduce their carbon emissions. For larger private fleets, this may mean transitioning to ZETs to reduce their direct emissions from their owned vehicle assets. For smaller and/or for-hire fleets, this may mean responding to shippers' desires to reduce their indirect (Scope 3) emissions by transitioning to ZETs and reporting on emissions reductions to these customers.[19]

18 For more information on Cal Fleet Advisor and Mass Fleet Advisor, visit their websites at https://calfleetadvisor.org and https://www.massfleetadvisor.org, respectively.

19 Scope 1 refers to emissions that an organization owns or controls directly. Scope 2 refers to emissions that a company causes indirectly and come from the energy it produces or purchases. Scope 3 refers to emissions not produced by the company but for those that the company is indirectly responsible for up and down its value chain.

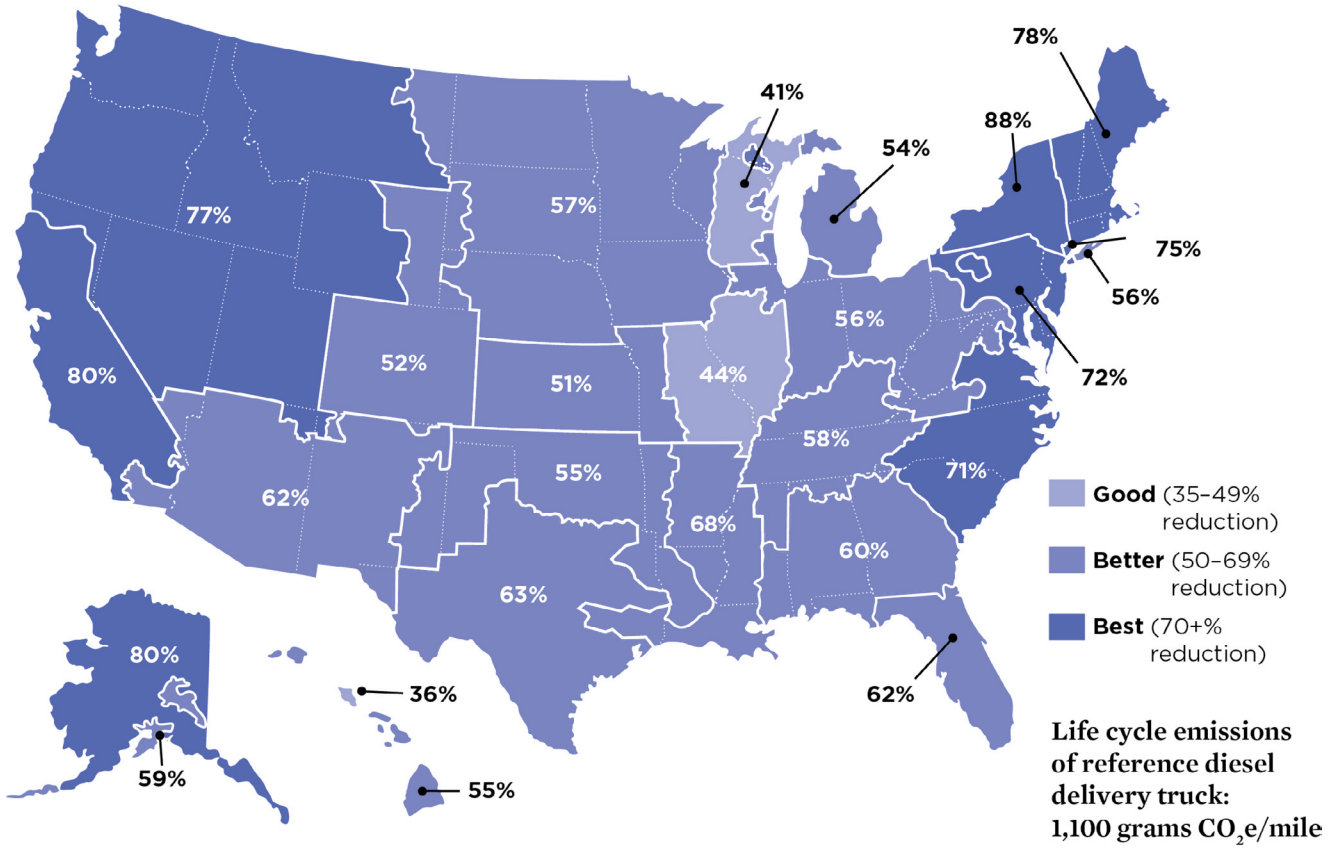
Companies will soon be required to report on their direct and indirect GHG emissions due to a group of landmark climate disclosure bills in California (PWC, 2023). Climate-related disclosures may also soon be required nationwide under a proposal from the U.S. Securities and Exchange Commission (Copley, 2023).

By deploying ZETs, fleets may be better positioned to win contracts from sustainability-minded shippers and/or to earn a premium from these contracts. Even private fleets can benefit by attracting top talent and increased investment thanks to their reduced climate risk. More than 100 fleets have already made commitments to reduce emissions and/or deploy ZETs (Environmental Defense Fund, 2023).

MOVING BEYOND TAILPIPE EMISSIONS TO TACKLE FULL VALUE CHAIN

While it is true that ZETs already offer lower lifecycle emissions than combustion trucks (Figure 14)—savings that will only grow as the electric grid integrates more renewable energy—it is crucial to continue to reduce emissions not just from the truck's tailpipe but from specific processes throughout the vehicle's value chain, such as mining, battery recycling, and manufacturing (O'Dea, 2019). Doing so acknowledges the interconnectedness of the entire lifecycle of a vehicle. A holistic approach can ensure a comprehensive reduction in transportation-related emissions and reinforce the commitment to combat climate change and build a more sustainable future.

Figure 14. Lifecycle GHG Emissions Reductions of ZETs Compared to Diesel Trucks Across the United States (O'Dea, 2019)



Mining battery minerals is vital for manufacturing ZETs, and the United States aims to bolster domestic mining production to meet rising ZET demand. Presently, the United States imports most battery minerals from global mining hubs like China, Chile, and Argentina. Estimates suggest sufficient capacity until 2030, but expansion will be necessary thereafter, partly due to IRA incentives favoring U.S. or allied country sourcing. A recent encouraging analysis from Lawrence Berkeley National Laboratory found that California's Salton Sea has even more lithium than previously thought: up to 18 million metric tons, enough for roughly the equivalent of 382 million electric vehicle batteries (Dobson et al., 2023).

Nonetheless, mining raises environmental and social concerns such as energy consumption, emissions, habitat loss, water contamination, and human rights. Outdated U.S. mining laws are under review, and the interagency Working Group on Mining Reform recently published recommendations to improve mining on public lands. The working group suggests significant reforms to the outdated General Mining Law of 1872 with 65 recommendations across six broad issue categories: improving mineral exploration and development planning and permitting, increasing engagement with stakeholders and potentially affected communities, expanding consultation and engagement with Tribes, obtaining fair compensation for taxpayers, protecting taxpayers from the cost of abandoned mine reclamation, and revitalizing domestic mining and other issues (Interagency Working Group on Mining Laws, Regulations, and Permitting, 2023). The Initiative for Responsible Mining Assurance (IRMA) offers third-party assessments for more responsible mining (IRMA, 2023). Encouraging IRMA certification for mining companies and advocating for its adoption in battery supply chains will enhance self-reliant and efficient battery production for ZETs.

Addressing the full environmental impact of ZETs involves more than upgrading the domestic supply chain; it requires consideration of the emissions associated with mining and manufacturing. While ZETs reduce tailpipe and lifecycle emissions, mining and battery manufacturing still produce substantial GHG emissions. To mitigate this, a focus on battery recycling and reuse is essential to promote a circular economy and lower ZETs' overall carbon footprint. Estimates suggest that if 50 percent of collected end-of-life batteries are recycled, and the other 50 percent are repurposed, mineral demand could be reduced by 28 percent by 2050, subsequently lowering mining emissions (The International Council of Clean Transportation, 2023). Furthermore, in some cases, recycled batteries have been shown to perform better than new ones (Wilkerson, 2022). Funding totaling $74 million to advance domestic battery recycling and reuse has already been awarded (DOE, 2022). While the current battery second-life and recycling market is small, it is due for a significant increase by 2030 as the number of battery-electric vehicles on the road increases. Advocating for supportive policy that encourages battery labeling and traceability requirements, recycling recovering rates and standards, and supporting the development of these markets will be crucial for a successful battery ecosystem. Creating a circular battery ecosystem now will enable the United States to reap the full benefits of a battery's lifecycle in the future.

After eliminating a vehicle's exhaust pipe with a ZE powertrain, producing the steel and aluminum used in vehicles is the second largest source of lifecycle emissions. Steel and aluminum make up roughly half of a vehicle's production emissions, with some estimates attributing as much as 80–85 percent[20] (Lie et al., 2021). Green steel—produced via more sustainable methods than traditional steel—offers a solution

20 Confidential interview with CALSTART member-company.

for reducing emissions from manufacturing. While the United States has seen less activity around green steel than in Europe, there are a few policies in place that impact U.S. steel and aluminum decarbonization. The Bipartisan Infrastructure Law and IRA granted DOE's Office of Clean Energy Demonstrations $6.3 billion for industrial decarbonization projects (Office of Clean Energy Demonstrations, 2023). This funding will target steel and other sectors. California's Buy Clean California Act run by the Department of General Services sets global warming potential limits on the procurement of steel and other materials used for state construction projects (Department of General Services, 2021). The federal government is also enacting a similar Buy Clean Initiative, again focusing on government construction (Office of the Federal Chief Sustainability Officer, 2023). These investments and regulations can better accelerate and create more opportunities to transition to near-ZE steel and aluminum procurement.

While regulations primarily target exhaust emissions in vehicle-related transportation, it is crucial to recognize that emissions also originate from components beyond the exhaust system. Tires and brakes, for instance, emit particulate matter at higher rates than newer model year truck tailpipes, posing potential health and environmental hazards. These non-exhaust emissions have historically been less regulated due to measurement and control challenges. Notably, BETs generate increased tire wear due to their weight and torque characteristics. Particulate matter, especially PM2.5, from these sources can directly enter the bloodstream and is associated with health issues (Carrington, 2022). Regenerative braking has promise to reduce brake wear and overall emissions from tires and brakes, but it is still unknown to what extent those reductions would be. As emissions standards become stricter, understanding and mitigating non-exhaust emissions will be imperative. California is leading efforts by requiring research into safer alternatives to tire chemicals like 6PPD (Department of Toxic Substances Control, 2023). Additionally, embracing alternatives in freight transportation, like electric cargo bikes for last-mile delivery, can further reduce tire and brake emissions. Although non-exhaust emissions are complex to regulate, investing in research can guide future technological advancements for emissions reduction.

HYDROGEN FUEL CELL DEVELOPMENTS

Compared to BETs, FCEV technology has the ability to offer longer ranges, faster fueling, and increased payload that are needed for demanding duty cycles seen in the HD long-haul segment. As such, FCEVs have seen increased interest from the trucking industry. As of June 2023, there have been approximately 15 FCEVs deployed in the United States, a number that is expected to grow rapidly with more OEMs committed to manufacturing and selling these vehicles. For example, Hyundai has brought the XCIENT FCEV to the United States, and other OEMs including Nikola, Kenworth, and Hyzon expect to increase FCEV production in the coming years.

However, with a new technology comes barriers to adoption, such as high upfront costs, an undeveloped refueling network, and complicated logistics, all of which have impeded the technology's adoption. Stakeholders are also hesitant to invest in fuel cell technology as a decarbonization tool due to the fact that the vast majority of hydrogen fuel produced today is made using a GHG-intensive process. The significant upstream emissions from production of this "grey" hydrogen are a challenge for sustainability-minded fleets. "Blue" or "green" hydrogen can be produced using more environmentally friendly methods like

carbon capture and storage or electrolysis using renewable electricity, respectively. However, blue and green hydrogen are significantly more expensive than grey hydrogen.

That said, FCEV adoption is slowly progressing, as seen in record dollar amounts being committed to all phases of the hydrogen process. For example, incentive programs in California, New York, Nevada, and Massachusetts have all started to incentivize FCEVs by reducing the upfront costs by way of a voucher or rebate. In addition, the Biden-Harris Administration recently selected seven projects for regional hydrogen hubs that will receive $7 billion in funding to accelerate the domestic market for clean and low-cost hydrogen (The White House, 2023). DOE has also launched the Clean Hydrogen Electrolysis Program that has $1 billion to improve the efficiency and cost-effectiveness of clean hydrogen (Office of Energy Efficiency and Renewable Energy, 2022). This program allows for research, development, demonstration, commercialization, and deployment projects.

The Million Mile Fuel Cell Truck (M2FCT) consortium, which is DOE-funded, aims to improve the durability and efficiency challenges with FCEVs and has an initial focus on long-haul trucking (M2FCT, n.d.). Continuing and expanding on efforts like this will be important to continue the technological development of FCEVs to handle the demands of harder-to-decarbonize duty cycles like long-haul trucking. Continued investment, research, and partnerships to advance FCEVs are needed to meet climate goals.

DEPLOYMENTS MOVING FROM PILOTS TO SCALE

Most fleets have historically purchased only one or two ZETs at a time to pilot in their operations. However, as they gain familiarity and trust in the technology, some fleets are now beginning to deploy ZETs at scale.

For example, as part of its Climate Pledge, Amazon has deployed more than 10,000 electric delivery vans across the country in approximately 18 months (Amazon, 2023). These vans are now on the road in more than 1,800 cities across the country and have delivered more than 260 million packages to customers. To support these vans, Amazon has installed over 12,000 chargers at more than 100 delivery stations across the United States. These deployments are part of Amazon's partnership with Rivian to put 100,000 electric delivery vehicles on the road by 2030.

A lineup of Amazon's electric delivery vans. Photo Credit: Amazon

Meanwhile, the CARB-funded Joint Electric Truck Scaling Initiative (JETSI) is working with fleets to successfully deploy ZETs and infrastructure at scale. Fleet partners National Freight Industries (NFI) and Schneider will each operate 50 Class 8 ZETs in regional-haul and/or drayage operations in Southern California (CARB, n.d.). In fact, Schneider's HD electric truck fleet has already achieved the impressive milestone of hauling more than 1 million ZE miles of customer freight (Schneider, 2023). Also in California, Performance Team has ordered 110 VNR Electrics from Volvo Trucks to operate in its Southern California port drayage and warehouse operations, adding to the 16 VNR Electrics it deployed in 2021(Achelpohl, 2022). 4 Gen Logistics has ordered 20 Kenworth T680E electric Class 8 trucks as part of its commitment to becoming a ZE fleet by 2025—10 years before California requires drayage trucks operating in the state to achieve that standard.

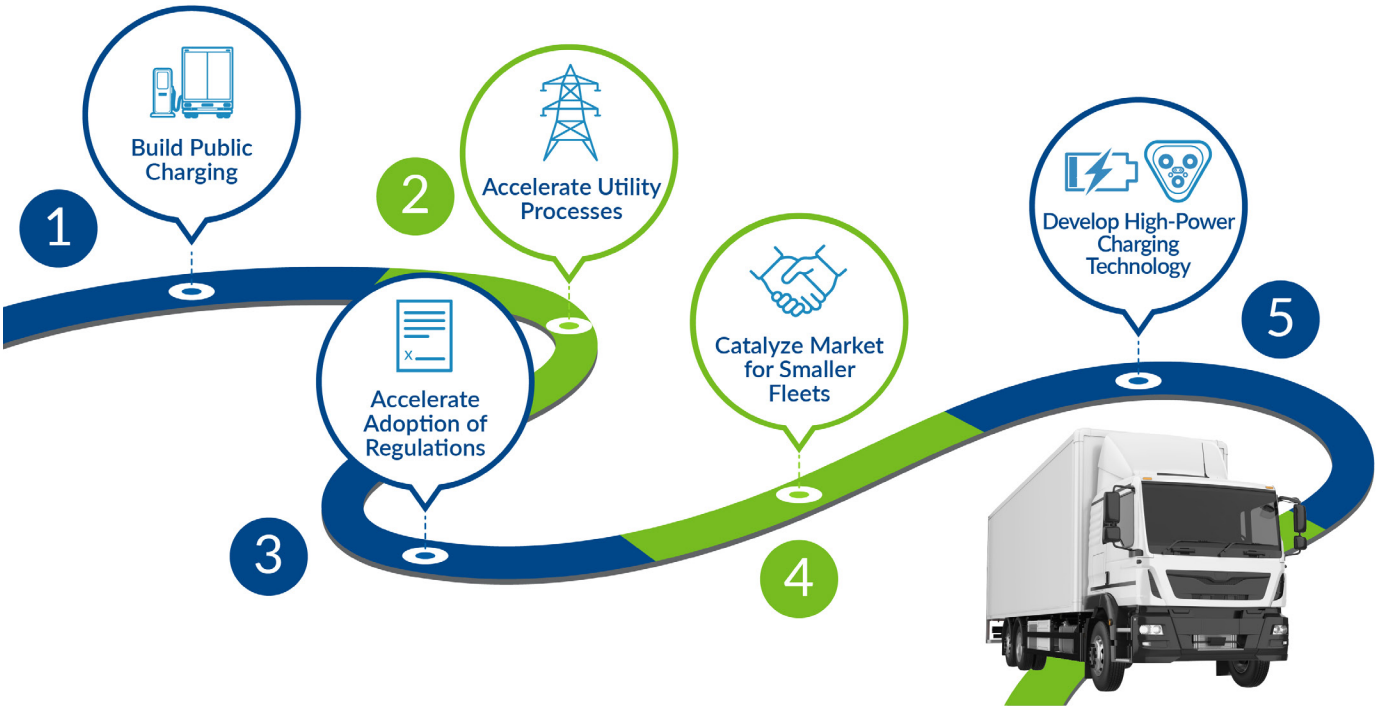
In addition, the North American Council for Freight Efficiency's (NACFE's) 2023 Run on Less Electric DEPOT event profiled 10 fleet depots in the United States and Canada with at least 15 ZETs operating at each one (NACFE, n.d.). The 10 depots operated 291 electric trucks, 22 of which shared data throughout the three-week Run. Through the Run, NACFE was "able to show that adopters of battery electric vehicles have demonstrated that they work at scale in various segments of the trucking industry including vans and step vans, medium-duty box trucks, terminal tractors and heavy-duty regional haul," said NACFE's

executive director, Mike Roeth (NACFE, 2023). Findings also highlighted the importance of the people involved—their diversity, passion, and capability—to scale the adoption of electric trucks. Data-sharing, such as the work done in Run on Less, is sorely needed in the industry so that others can learn from the successful and growing, but still mostly undocumented, real-world experiences.

NEXT STEPS TO ACCELERATE THE TRANSITION

Though ZET deployments continue to grow, more action is needed to spur the market growth justified by environmental justice considerations and climate science and to be ready to comply with existing and anticipated regulations. The following measures represent the top five opportunities for accelerating ZET deployments in the coming months and years (Figure 15).

Figure 15. Roadmap to Accelerate U.S. ZET Market



1. BUILD PUBLIC CHARGING

As noted in the *Unprecedented Investments in Charging Infrastructure* section above, billions of dollars have already been invested in building out charging infrastructure for ZETs. While there are few public chargers open to ZETs today, many are expected to come online in the coming years. And though significant additional investment is needed, it is important to note that not all of this infrastructure is

needed at once—it can be phased in. CALSTART's *Phasing in U.S. Infrastructure* working paper outlines a modeled scenario of how to accelerate infrastructure buildout for MHD vehicles, starting in priority launch areas that have favorable policy, investment, industry concentration, and grid modernization, then building out toward key hubs and corridors that will create a national network through 2035 (Joseph et al., 2023). The infrastructure buildout meets the pace set forth by the Global MOU. This approach allows for cost-effective implementation while signaling to utilities, governments, and investors where they need to target their actions. The outlined roadmap (Figure 16) shows that change is possible through focused, intentional action and investment, and if followed, allows the United States to stay on track to meet climate and ZET sales goals.

Figure 16. Phase-in of Infrastructure to Meet Rapid ZET Adoption (Joseph et al., 2023)

The Biden-Harris Administration has also announced $7.4 million in funding for ZE MHD vehicle corridor projects to help accelerate the creation of an MHD charging network (DOE, 2023c). The federal government also offers funding for public truck charging via the Charging and Fueling Infrastructure discretionary grant program, which has an approved budget of $2.5 billion over five years (FHWA, 2023).

Public charging buildout will be critical to not only ensure overall ZET deployments increase but also small fleets are not left behind in the transition.

2. ACCELERATE UTILITY PROCESSES

As noted earlier in this report, antiquated utility processes designed for real estate development can result in necessary site upgrades taking years to complete before charging infrastructure can be deployed. Given the incredibly fast timeline for transitioning the nation's truck fleet to ZETs, utilities, regulators, policymakers, and industry must work together to update and hasten timelines for grid assessments, upgrades, and electric vehicle supply equipment energization.

As utilities and the electrical supply chain work to adapt to the rapid growth of the ZE MHD sector, fleets have been seeking interim and innovative solutions like the "3 M's" mentioned above: mobile charging, managed charging, and microgrids. There are an increasing number of mobile-charging hardware solutions on the market capable of charging ZETs without needing grid upgrades (CARB, 2023a). Often skid-based or containerized, these solutions are now offered by several OEMs, with some models available for purchase outright while others are available to customers via a lease program. In addition, managed charging software can help fleets limit electricity demand at any time, making grid upgrades less needed and saving money on electric bills by minimizing demand charges and time-of-use rates. Microgrids, including distributed energy resources like onsite solar panels and battery storage, can also minimize utility bills and needed upgrades, potentially even enabling fleets to charge vehicles completely independent of the local electric utility. Companies like Scale Microgrids can help fleets plan and execute optimized solutions (Scale Microgrid Solutions, 2022).

Changing utility regulations to enable them to proactively build no-regret infrastructure to support ZET charging (rather than simply being reactive to individual fleet customer requests) is also being considered as a way to minimize timelines for deploying charging infrastructure. Standardizing and streamlining permitting processes would also hasten this process.

3. ACCELERATE ADOPTION OF REGULATIONS

As noted above in the *Expansion of Regulations to Additional Geographies* section, regulations like ACT have been incredibly important drivers of ZET deployments to date. However, the majority of states have yet to adopt this regulation. Doing so would send a strong market signal to OEMs, fleets, utilities, and charging providers while promoting consistency and regulatory certainty. States may follow California's leadership by adopting ACF as well.

On the federal stage, the industry is awaiting EPA's final "Phase 3" standards to reduce GHG emissions from HD vehicles. These regulations will begin in model year 2027, and the proposed standards maintain the flexible structure created in EPA's Phase 2 GHG program, which is designed to reflect the diverse nature of the HD industry. EPA should finalize a strong Phase 3 standard as soon as possible to support the work of states, send clear nationwide market signals, and help unlock the investments necessary to support clean transportation. Investments in research, development, and production of ZETs will in turn drive innovation and economies of scale, ultimately resulting in more affordable and accessible ZET options for consumers.

Additional policies that should be pursued to accelerate ZET deployments include: enacting low carbon fuel standards that provide funding to fleets using electricity rather than diesel as a fuel, enabling utility make-ready programs to cover the cost of necessary grid-side upgrades to support charging and refueling infrastructure, and exempting HD ZETs from the federal excise tax that exacerbates the price premium challenge of ZETs and prolongs the timeframe for these vehicles to achieve cost parity with combustion trucks.

4. CATALYZE MARKET FOR SMALLER FLEETS

Though there have been significant effort and investments made to help small fleets access ZET technology, more are still needed. In addition to the technical assistance, financial incentives, and as-a-service business models mentioned above, small fleets will not be able to adopt ZETs at scale without a used ZET market, access to reasonable financing and insurance, and clear signals from customers.

The secondary market in the trucking industry plays a vital role in allowing fleets the opportunity to purchase cleaner yet affordable trucks. Smaller fleets often look to the used truck market to buy their vehicles, as this route is better financially for them and it allows larger fleets the opportunity to recoup value from their trucks. The used truck market is expected to grow at 9 percent CAGR (compound annual growth rate) from 2023 to 2032, and its current market size surpassed $40 billion in 2022 (Wadhwani, 2023). However, the used truck market is currently non-existent for ZETs. This is due in large part to the fact that most ZETs have not been on the road long enough to be resold. Seeding a secondary market by encouraging ZET deployment pioneers to turn over their first-generation ZETs will make ZETs more widely available and more affordable, but it will also provide valuable data to financers that currently have no information about the resale value of ZETs.

A current hindrance to ZET adoption has been the ability for fleets to secure loans from financial institutions. As of today, most leases of ZETs treat the residual value of the vehicle as zero, which in turn prompts higher monthly lease values that some fleets cannot afford. Having a robust used ZET market allows financial institutions to gather relevant data on ZETs and allows them to offer more affordable loans to fleets in need. A secondary market for ZETs and their components can also help bring down insurance premiums, which can be astronomically high today and are impeding ZET adoption.

Small fleets also need clear market signals and innovative collaboration with customers. For example, shippers can offer green premiums and/or preferential contracting with carriers that utilize ZETs. They may also require carriers to reduce and report on their carbon emissions by transitioning to ZETs, thereby helping shippers to reduce and report on their Scope 3 emissions.

5. DEVELOP HIGH-POWERED CHARGING TECHNOLOGY

For most ZETs on the market today, charging speeds currently max out around 350 kilowatts (kW), resulting in longer-than-optimal recharge times and/or reduced payload capacity and increased costs caused by the need for more batteries to meet the range requirements of a truck's duty cycle without

having to stop to charge. Because of this tradeoff, there is a need for faster charging technology.

For example, the Tesla Semi can charge at much higher power levels, enabling it to recoup up to 70 percent of its 300- to 500-mile range in 30 minutes (Tesla, n.d.). Tesla has installed direct current (DC) fast chargers up to 750 kW at PepsiCo's Sacramento location (NACFE, n.d.a). With this fast-charging capability—on both the vehicle and charger side—PepsiCo was able to demonstrate more than 1,000 miles per day for a Class 8 electric truck operating in real-world regional-haul routes. This is about four times the average 250 miles per day from the competing Freightliner and Volvo Class 8 electric trucks (Wang, 2023).

The Megawatt Charging System (MCS) represents a significant leap forward in the realm of electric vehicle charging technology, particularly for ZETs. This groundbreaking standard emphasizes high-capacity charging solutions capable of delivering multiple megawatts of power to electric trucks rapidly, allowing for charging times less than 15 minutes to get from zero to 100 percent state of charge. By enabling faster charging at unprecedented power levels, MCS not only reduces downtime for commercial fleet operators but also enhances the practicality and competitiveness of electric trucks in HD applications. Led by CharIN, a task force was created in 2018 to create a common solution for charging electric HD vehicles within a reasonable timeframe. Since the task force formation, an MCS white paper has been released, requirements for an MCS system have been established, and a connector compatibility test was successfully completed, with more milestones ahead. This technology not only accelerates the transition to cleaner transportation but also underscores the growing synergy between innovative charging infrastructure and the broader goals of sustainable and efficient freight and logistics operations.

CHAPTER IV

CONCLUSION

ZETs are being deployed across the United States at an increasingly rapid pace due to increasing model availability, incentives, regulations, and available refueling infrastructure, among other developments. Yet, more action is needed to align the trucking industry's transition with the pace required by science and committed to by key U.S. policymakers.

In 2024, improvements are needed across the charging sector, with an emphasis on increasing the amount of public and shared charging available for ZETs, speeding up the energization and permitting processes, and making additional advancements into high-powered charging capabilities. Utilities, public utility commissions, charging developers, local governments, and states must all work together to achieve these needed improvements. States must also continue to adopt ZET sales mandates and implement incentive programs for vehicles and charging. Together, these policies will send a strong market signal, resulting in increased production volumes and lower prices from OEMs.

Further research and development are needed to advance battery and fuel cell technology and to create a more sustainable battery supply chain. Advances in clean hydrogen production and distribution will be required to meet growing demand for increasing options of fuel cell trucks. Market barriers must also be minimized—not just for large, well-resourced fleets but for small businesses and independent owner-operators as well. Shippers have an important role to play in de-risking ZET investments by their carriers.

The transition will no doubt be challenging, but by rapidly deploying increasing numbers of ZETs, the U.S. trucking industry will be able to continue its vital work while eliminating climate change- and disease-causing emissions, repairing relationships with the communities in which it operates, and doing its part to help the country achieve its climate, energy, and air quality targets.

This transition will require unprecedented collaboration from stakeholders across the industry, including fleets, OEMs, utilities, charging providers, shippers, regulators, policymakers, academia, nonprofits, and frontline communities. Everyone has a role to play to ensure the pace and success of this transition. This report will continue to be updated with ZET deployment statistics to provide a measure of progress, identify opportunities for further action and increased impact, and inspire collective action and investment.

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APPENDIX A

STATE INCENTIVE PROGRAMS

Table A-1. State Incentive Programs

State	Incentive Program	Incentive Type	Funding	Year Started
California	California's Clean Truck and Bus Voucher Incentive Project (HVIP)	Voucher	Vehicle	2010
California	Clean Off-Road Equipment (CORE) Voucher Incentive Project	Voucher	Vehicle	2021
California	Energy Infrastructure Incentives for Zero-Emission (EnergIIZE) Commercial Vehicles	Voucher	Infrastructure	2022
California	Implementation of MHD Vehicle Infrastructure	Grant	Infrastructure	2023
Colorado	Clean Fleet Vehicle Technology Grant Program	Grant	Vehicle	2023
Colorado	Fleet Zero	Grant	Infrastructure	2023
Delaware	EV Charging Equipment Rebates	Rebate	Infrastructure	2023
Federal	Commercial Clean Vehicle	Tax Credit	Vehicle	2023
Hawaii	Diesel Replacement Rebate	Rebate	Vehicle	2023
Maryland	MHD ZEV grant program	Grant	Both	2024
Massachusetts	Massachusetts Offers Rebates for Electric Vehicles (MOR-EV) Trucks Program	Rebate	Vehicle	2022
Massachusetts	MassEVIP	Grant	Infrastructure	2014
Nevada	Nevada Clean Trucks and Buses Program	Grant	Vehicle	2024

State	Incentive Program	Incentive Type	Funding	Year Started
New Jersey	New Jersey Zero Emission Incentive Program (NJ ZIP)	Voucher	Vehicle	2020
New Jersey	Clean Fleet Electric Vehicle Incentive Program	Grant	Both	2023
New York	New York Truck Voucher Incentive Program (NYTVIP)	Voucher	Vehicle	2011
New York	New York City Clean Trucks Program (NYCCTP)	Voucher	Vehicle	2012
Oregon	Rebate Program for Medium and Heavy Duty Zero-Emission Vehicles	Rebate	Vehicle	2024
Pennsylvania	Medium- and Heavy-Duty Zero Emission Vehicle Fleet Pilot Grant	Grant	Both	2023
Pennsylvania	Alternative Fuels Incentive Grants	Grant	Vehicle	2022
Washington	Clean Alternative Fuel Commercial Vehicles and Vehicle Infrastructure	Tax Credit	Both	2020
Washington	EV Charging Infrastructure Program	Grant	Infrastructure	2023
Washington	Infrastructure and Incentive Program for Medium and Heavy Duty Zero Emission Vehicles	TBD	Both	2024

APPENDIX B

UTILITY MAKE-READY PROGRAMS

Table B-1. Utility Make-Ready Programs

Utility	State	Program Name
Alabama Power	Alabama	Make Ready Program
Southern California Edison (SCE)	California	Charge Ready Transport
Pacific Gas & Electric (PG&E)	California	EV Fleet Program
San Diego Gas & Electric (SDG&E)	California	Power Your Drive for Fleets
Public Service of Colorado (Xcel Energy)	Colorado	Public Charging EV Solutions
United Illuminating	Connecticut	CT EV Charging Program
Eversource Energy	Connecticut	EV Charging Program
Georgia Power Company	Georgia	Make Ready Infrastructure Program
Hawaiian Electric	Hawaii	Charge Up Commercial
Entergy New Orleans	Louisiana	EVCS
DTE Energy	Michigan	eFleet
Consumers Energy	Michigan	PowerMIFleet
Entergy Mississippi	Mississippi	EVCI
Public Service Company of New Mexico	New Mexico	Transportation Electrification Program
Rochester Gas and Electric Cooperative	New York	MHD Make-Ready
New York State Electric and Gas	New York	MHD Make-Ready
Central Hudson	New York	MHD Make-Ready
National Grid	New York	MHD Make-Ready

Utility	State	Program Name
Orange and Rockland Utilities	New York	MHD Make-Ready
Portland General Electric	Oregon	Fleet Partner
Duquesne Light	Pennsylvania	EV Fleet Electrification
State of New Jersey Board of Public Utilities	New Jersey	Clean Fleet Electric Vehicle Incentive Program

APPENDIX C

STATE POLICY ADOPTION

Any states not listed in Table C-1 had not adopted any of the policies tracked in this report as of June 2023.

Table C-1. State Policy Adoption (As of June 2023)

State	MOU	ACT	ACF
California	Yes	Yes	Yes
Colorado	Yes	Yes	No
Connecticut	Yes	No	No
District of Columbia	Yes	No	No
Hawaii	Yes	No	No
Massachusetts	Yes	Yes	No
Maryland	Yes	No	No
Maine	Yes	No	No
North Carolina	Yes	No	No
New Jersey	Yes	Yes	No
Nevada	Yes	No	No
New York	Yes	Yes	No
Oregon	Yes	Yes	No
Pennsylvania	Yes	No	No
Rhode Island	Yes	No	No
Virginia	Yes	No	No
Vermont	Yes	Yes	No
Washington	Yes	Yes	No

APPENDIX D

DATA SOURCES

Sources in Table D-1 are in order from most to least prevalent within the data used to determine ZET deployments.

Table D-1. Data Sources

Data Source	Description	Specific Data Used
Private Correspondence	Author correspondence with OEMs	ZET deployments as of June 2023
IHS Markit	Global provider of information and analysis on world markets and industries	U.S. truck registrations as of June 2023
MarkLines	Information service that provides essential information about automotive production from countries around the world	ZET deployments as of June 2023
California CORE	California's Clean Off-Road Equipment Voucher Incentive Program	ZE yard tractor deployments as of June 2023
Public Press Releases	Press releases from OEMs announcing delivered sales	ZET deployments as of June 2023
California HVIP	California's Clean Truck and Bus Voucher Incentive Project	ZET deployments as of June 2023
NYTVIP	Truck voucher incentive program administered by the State of New York	ZET deployments as of December 2021