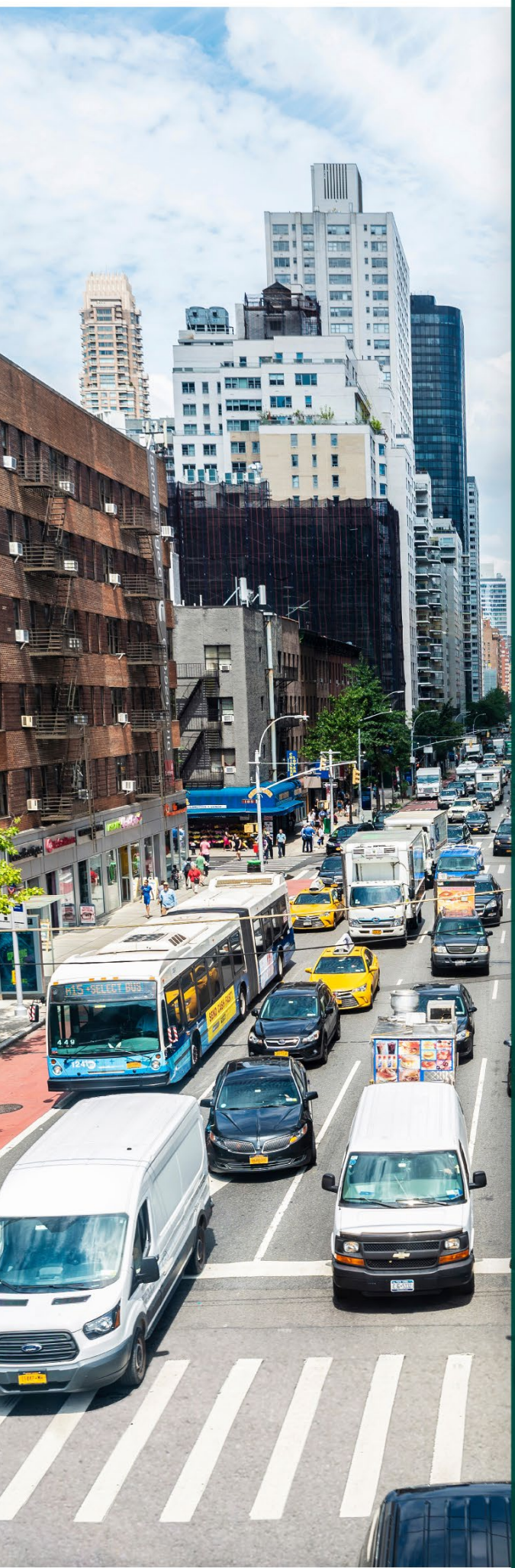

THE STATE OF SUSTAINABLE FLEETS

2023 MARKET BRIEF

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Related Material

State of Sustainable Fleets 2020 is the foundational assessment that laid the groundwork for this annual brief, now in its fourth year of publication. It provides readers with additional background and historic data and analysis on leading sustainable technologies for fleets, available at: https://www.stateofsustainablefleets.com/download-report-2020/

GNA produces a short "Fleet Miniguide" on planning to adopt each of the four leading clean vehicle drivetrain technologies covered in the State of Sustainable Fleets. Current and previous miniguides for each of the following technologies are available on the website:

- Propane Vehicles
- Natural Gas Vehicles
- Battery-Electric Vehicles
- Fuel Cell Electric Vehicles

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ABOUT THE 2023 MARKET BRIEF

The 2023 State of Sustainable Fleets Market Brief is a technology-neutral analysis of key insights and critical trends for today's leading on-road clean vehicle technologies.

Building on four years of market reporting and 30 years of GNA's industry leadership, the 2023 edition provides concise insights on key trends and developments in the vehicle, fuel, and infrastructure segments of clean commercial transportation.

By gathering real-world data directly from early adopter fleets, the State of Sustainable Fleets provides sector-specific insights into the adoption of four leading clean medium- and heavy-duty vehicle technologies – drivetrains powered with propane, compressed natural gas, electric batteries, and hydrogen fuel cells – against a baseline of diesel technology. The comprehensive findings within this document represent government and private sector fleets and are gathered across several sectors including school, shuttle, state/county/municipal, urban delivery, refuse, utility, transit, regional-haul, long-haul, drayage, and off-road cargo handling.

About the 2023 Fleet Survey

At its core, the 2023 Market Brief is informed by a robust fleet survey capturing input on clean vehicles and infrastructure from 225 fleet operators and decision-makers, a response rate that has more than doubled since 2020.

Building upon a rich data source covering a broad range of real-world fleets in every stage of technology adoption ensures that this Brief provides a comprehensive representation of today's fleet landscape.

Using the Findings

The State of Sustainable Fleets is a guide for fleet operators and the industry as it navigates a time of unprecedented change. Developments in the vehicle and fuel markets are occurring so rapidly that an exact assessment is impossible. Each year, the survey results are complemented by secondary data and input from the industry's leading experts (see Methodology). This methodology yields the most comprehensive and robust reflection of the industry available today, supporting – but not substituting for - the custom evaluations that fleet owners must do to identify the best-fit solution for their business.

INTRODUCTION

The first three years of State of Sustainable Fleets demonstrated that some clean fuels and vehicles are now superior to gasoline- and diesel-fueled vehicles for many fleet applications, and adoption of renewable fuels and advanced technology drivetrains is accelerating. Those findings are especially true for many heavy-duty (HD) transit, refuse, and logistics fleets using compressed natural gas (CNG), increasingly powered by low-carbon renewable fuel. Medium-duty (MD) and school bus fleets using propane are also finding operational and cost benefits because both propane and CNG are proven, mature technologies with low fueling costs.

This year's Market Brief tells us much more about the future, one where new diesel engine development programs are moving towards a sunset, and zero-emission vehicles (ZEVs) will be the "law of the land" in states representing around half of the U.S. economy.

The rise of zero-emission states, the sunset of diesel development

The past 18 months have laid the roadmap for a zero-emission (ZE) future in many states and produced early signals that the era of the diesel engine, the workhorse of HD vehicles, will sunset sooner than many predicted. The U.S. Environmental Protection Agency (EPA) finalized a HD engine rule in late 2022 that sets the strictest national standards ever on emissions that contribute to air pollution. It joins a similar rule previously passed in California and is expected to add tens of

thousands of dollars to the cost of a diesel tractor. In anticipation of these increasingly stringent air quality regulations and accelerated federal and state ZE goals, at least two HD vehicle manufacturers signaled plans for the post-diesel development era, one of which gave a date for sunsetting. Announcements by more manufacturers to sunset HD diesel programs are expected to follow soon.

A windfall of public sector funding and new state-level mandates foreshadow aspects of the ZEV future. Public incentive funding for clean fleet technologies soared to historic highs in 2022 with the Inflation Reduction Act (IRA) following 2021's Infrastructure Investment and Jobs Act (IIJA). Incentive funding is expected to average $32 billion annually for the next four to five years, much of it with an emphasis on building the ZEV market. A total of 13 states and the District of Columbia have passed or are considering some form of California's mandate for manufacturers to begin selling ZEVs. California just passed a new mandate for fleets to begin transitioning to ZEVs that states which have or are going to adopt the ZEV sales mandate are expected to consider adopting. While regulation and public incentive funding were critical to establishing the market for the near-zero technologies of CNG and propane as leading clean technologies, for more than 40% of the U.S. population represented by the states adopting ZE mandates, the future is now firmly focused on ZEVs.

> Funding is expected to average **$32 billion** annually for the next four to five years, with a focus on the ZEV market.

The future of alternative fuel and vehicle technologies: No longer the alternative

The supply of many clean technologies and fuels is growing dramatically along with growing demand. Production

capacity for renewable diesel (RD), a replacement for fossil diesel, doubled in 2022, while uptake by private sector fleets in the annual survey rose nearly 10% compared to 2021. Fleets have fully replaced their fossil-based CNG with renewable natural gas (RNG) in California during the past two years, and growth is strong nationally. Propane and CNG vehicle sales remain steady, at more than 4,500 and 6,200 units last year, respectively. New engines coming to the market for both fuels will unlock their benefits for new fleet types. Orders for MD battery-electric vehicles (BEVs) surged to nearly 30,000 units, mostly for Ford and General Motors (GM) products, while deliveries of commercial HD tractors began, despite persistently high costs and supply chain disruptions as manufacturers build capacity. Nearly every technology included in the State of Sustainable Fleets saw growth in both supply and demand this past year.

Plans to increase CNG, propane, battery-electric, and fuel-cell electric vehicle use by early adopters of these technologies — the clean drivetrains of State of Sustainable Fleets — has remained above 80% each year from 2020-2021, which was confirmed by this year's survey of 225 fleets. For the first time in the survey results,

75% of fleets that have never used leading clean drivetrain technologies plan to increase use in the next 5 years - a first in survey results.

fleets that have never used any of the leading clean drivetrain technologies are nearly equally motivated, with three-quarters intending to increase use in the next five years. These same fleets that have not yet tested new drivetrains in their operations report that the growing public incentives and regulatory mandates are their top two reasons to begin planning for use.

Given the confluence of regulatory mandates, vehicle manufacturer plans, public and private investment, and fleet actions driving the market for low-emission fuels and vehicles, a major milestone is near when fleets that have not used alternative vehicles become the minority. Sometime after that point, cleaner fuels and vehicles will no longer be alternative fuels and vehicles. This year's State of Sustainable Fleets reveals that this day may be closer than many think.

KEY FINDINGS

The regulatory and market landscape revealed more about the future than ever. The following predictions for the next few years will have transformational implications for the scope and pace of clean vehicle and infrastructure adoption by fleets.

Most heavy-duty OEMs will announce plans to sunset diesel development

Most HD OEMs will join Daimler and Navistar in announcements that portend the end of the diesel era given new regulatory and demand signals. While diesel vehicles will continue to lead for many years, manufacturers will increasingly shift investments into clean drivetrain development and production.

Adoption of state-level ZEV mandates will continue to expand

A memorandum of understanding (MOU) signed by 17 states and the District of Columbia set a goal of reaching 100% ZE sales for MD and HD vehicles by 2050. Although the MOU is voluntary, 13 of these states have taken action to reach the goal by adopting or beginning to adopt California's Advanced Clean Trucks requirement for ZEV sales in their states. Following California's passage of the Advanced Clean Fleets mandate on fleets to purchase ZEVs, these same states are expected to consider adopting it.

Key Finding: Public policy and funding shifts sharply to build the ZEV market and accelerate the sunsetting of diesel

Federal and state regulations and funding were crucial to establish and build markets for renewable fuels and natural gas and propane

vehicles during the past few decades. In 2022, federal and many state policymakers ramped up a trend that began the past few years with new laws and legislation aimed at requiring ZEV and associated infrastructure deployments. A total of 13 states and the District of Columbia have passed or are considering some form of California's 2020 Advanced Clean Trucks (ACT) mandate on vehicle manufacturers to begin selling ZEVs. These same states are expected to consider California's Advanced Clean Fleets (ACF) mandate that passed in April and requires many vehicle fleet operators to begin transitioning to ZEVs as early as 2024. Most of these same policymakers have directed historic levels of funding, averaging $32 billion per year for the next four to five years, to support vehicle purchases and install infrastructure that is mostly aimed at ZEVs.

The federal government and California have also passed rules requiring that diesel engines cut NOx emissions by 80%. The EPA's Clean Trucks Plan, passed at the end of 2022, joins California's even more stringent Heavy-Duty Low NOx Omnibus with requirements that take effect as early as 2024 in California and 2027 nationally. Engine manufacturers that have evaluated the solutions that will be needed to meet these requirements, including rigorous new testing procedures and longer useful life and warranties, expect compliance to add tens of thousands to the cost of a new diesel tractor, while likely requiring additional ongoing maintenance. In anticipation of a transition to new technologies that these and other signals have brought about, leading HD manufacturer Daimler Truck North America (DNTA) announced the "beginning of the end of the diesel era" and rival Navistar signaled plans to sunset their diesel development programs starting in 2027.

Key Finding: Value of efficiency and renewable fuel for diesel vehicles remains strong, renewable diesel supply growth continues

With diesel prices reaching historic highs in 2022 due to factors like the ongoing war in Ukraine and U.S. inflation — both of which are unlikely

to resolve in the near term — fuel efficiency and renewable fuels are ever more essential for fleets. Average per-gallon prices of gasoline and diesel rose by 41% and 56%, adding $0.80/gal and $1.50/gal to fueling bills, respectively, last year. While biodiesel (BD) blends and RD also saw prices increase, the highest BD blends offer about 5% savings compared to diesel, and fleets report equivalent-or-better prices for RD in states with carbon credit markets. Fleets that have adopted diesel alternatives can use BD to replace up to 20% of their diesel consumption, while RD is effectively a 1:1 replacement, and those same fleets in the annual survey report a preference for them when costs are near or at parity with diesel. Combined with efficiency technologies and practices, where most fleets can achieve an average 16% improvement in fuel economy and up to 9.6 miles per gallon with the newest tractors, these technologies offer cost and emissions benefits for many fleets that they can "drop-in" to their existing diesel fleet.

RD itself continued to experience dramatic supply grow and increased demand in states with carbon credit markets. In 2022, domestic RD production doubled from 800 million gallons in 2021 to more than 1.7 billion gallons. A significant drop in credit prices related to large volumes of renewable fuels in California's carbon credit market may reduce the rate of RD supply growth, but the industry still expects to reach its national 5-billion-gallon production capacity target in 2024, one year ahead of schedule. On the demand side, national RD consumption increased by more than 45% for the second year in a row, and it represented 83% of all bio-based diesel consumed in transportation in California for the first three quarters of 2023. For the first time since the inception of the annual State of Sustainable Fleets survey of fleets, more fleets report using RD than BD.

Key Finding: CNG and propane retain cost advantages while new vehicles entering the market expand options for fleets

CNG and RNG continue to offer price advantages compared to diesel, with long-term fuel supply contracts protecting fleets from market volatility. The national average public retail price of fossil CNG reached $2.73 per diesel-gallon equivalent (DGE) in 2022, and surveyed fleets report similar prices as well as an average of $3.11/DGE for RNG, with RNG purchased mostly in California. While the end of 2022 brought supply shortages that resulted in a price spike, it was short-lived, and a multi-year extension of the Alternative Fuel Tax Credit (AFTC) helps ensure ongoing price advantages. Combined with California's Low Carbon Fuel Standard (LCFS) market, it is a primary reason why more than 95% of natural gas used in transportation is now renewable for the second year in a row in the state.

Propane vehicles also continue to be a cost-effective solution for many MD and school bus fleets, with propane prices remaining lower than gasoline, even while year-over-year fuel prices rose by 15% to $2.10 per gasoline-gallon equivalent (GGE). Fleets using private fueling, which are the majority of propane vehicle adoptees, saved $1.94 per GGE over gasoline on average. The extended AFTC provides a tax credit of $0.36 per GGE for propane along with a 30% tax credit or up to $10,000 for fueling infrastructure investments through 2024.

Both fuels are supported with new vehicle options entering the market in 2024 that expand these technologies for additional applications. For natural gas, PACCAR has already announced plans to offer a 15-liter CNG engine with its Kenworth and Peterbilt brands, and other manufacturers are rumored to be considering it. Walmart is testing the X15N now at its Fontana, California location. With propane, MAFI revealed a propane yard truck design using PSI's 8.8-liter engine and Cummins will bring a 6.7-liter engine to market that could be suitable for off-road vehicles such as yard trucks. Manufacturers of many of the new CNG and propane engines aim for certification to the 0.02g/bhp-hr NOx standard to ensure that vehicles using them comply with new California and EPA standards.

Key Finding: Interest in battery-electric vehicles is high and broad, though supply, cost, and infrastructure barriers persist

BEV interest by fleets has grown to become the highest among clean drivetrains in the State of Sustainable Fleets survey, and it is spreading across a broad range of fleet types. According to respondents, 65% of surveyed fleets have used a BEV in the past two years and 92% of fleets with BEVs intend to grow their use in the next five years. For the first time among the technologies studied in this report, use reached at least 50% of respondents in all 11 of the applications — called "fleet types" — tracked in the annual survey. Interest is translating into demand in some applications: Orders for MD vehicles soared to nearly 30,000 in 2022, with most represented by Ford and GM products. Demand for HD vehicles remained steady overall, with tractor and transit vehicles seeing orders in the mid hundreds and school bus orders climbing to 2,400. Although interest is high and broad, BEVs currently comprise an average of 4% of a fleet's vehicle population per survey results, reflecting this technology's state as an early commercial product that fleets are still learning.

Supply chain disruptions, high costs, and infrastructure availability and reliability persist as barriers to larger deployments. Ford paused Lighting orders temporarily and Rivian slashed production targets, while Lightning eMotors reoriented to focus on repowers — three examples of manufacturers adapting to ongoing supply chain troubles. The more mature passenger car market saw raw materials costs rise 140% between May 2020 and May 2022, while battery prices rose by at least 14%. Changes in the passenger market suggest that commercial BEV prices also increased. The base price of a Class 8 BEV tractor is approximately $350,000 to $500,000, or three to five times the price of a new diesel truck. Fleets that overcome the vehicle price barrier can still face multi-year queues for electrical service and concern over charging during flex alerts and rolling brownouts and blackouts. Government and industry committed hundreds of billions of dollars to infrastructure development in 2022 to bridge the gap, but grid capacity must grow by 60% before 2030 to meet national electrification goals.

Key Finding: Public and private hydrogen investment emphasizes fueling, while commercial heavy-duty vehicle offerings expand this year

Public and private investments continue to focus on building the supply and infrastructure for hydrogen as a transportation technology. The U.S. Department of Energy (DOE) projects that the need for electrolyzer capacity, a technology that most experts consider essential to producing renewable hydrogen, must grow by 1,600%. The DOE will make a decision late this year on project applications to distribute $8 billion in funding designated by the IIJA to develop six to 10 regional "hubs" of production and distribution, several of which are expected to focus on renewable hydrogen.

Analysis suggests that hydrogen fuel production projects announced in 2022 will add more than 900 metric tons per day of hydrogen capacity by 2023. Station network growth to distribute this capacity has resumed, expanding 12% to 54 stations in 2022, all but one in California. Plans by infrastructure developers now include networks across the central, mid-Atlantic, and southwestern U.S. — a first for public hydrogen fueling networks outside of California.

Sales and deliveries of fuel cell electric buses for transit continued, while tractor demonstrations moved the technology closer to early commercial orders. Public announcements indicate that transit agencies and manufacturers prioritized filling existing orders in 2022 rather than placing new orders. The first Class 8 tractor demonstrations continued in 2022, with Hyundai preparing for its June 2023 demonstration of 30 Xcients in California and startup Hyzon delivering units to TTSI in California and Exxon Mobil in Texas. Nikola plans to make the first customer deliveries of a commercial fuel cell tractor in Q3 2023 after receiving approval in December from California to sell to in-state customers and apply for state incentives. Other OEMs that have announced fuel cell electric tractors include Hino and Kenworth, with some models available as early as 2024.

Federal, State, and Local Policy and Funding

The past year brought another windfall of funding and an added expansion of mandates that largely benefited ZEVs. Policy and funding played a crucial role in establishing and building markets for renewable-fuel, CNG, and propane vehicles during the past few decades. While those technologies still benefit from many established regulations and funding programs, the past few years have brought about a decided shift in focus by policymakers to build the market for ZEVs and associated infrastructure, as well as end the petroleum era - all on an accelerated timeframe.

New policy will add costs to diesel, trigger the sunset of engine development

The end of the year culminated with one of the most consequential new national air quality rules in a half century when the U.S. EPA issued its new Heavy-Duty Engine and Vehicle regulation in December 2022, known as the Clean Trucks Plan. This regulation sets strict low-emission standards for HD truck engines, starting with model year (MY) 2027. The rule requires engine manufacturers to reduce NOx emissions for MD and HD engines from the current standard of 0.2 grams per horsepower-hour (g/hp-hr) to 0.035 g/hp-hr for MY2027. In addition to very low emission standards, these new rules also set new requirements for emission testing, certification procedures, and extended in-use service and warranty requirements. The Truck and

Engine Manufacturers Association estimates that these requirements could add up to $30,000 to the cost of a new Class 8 tractor while likely requiring additional ongoing maintenance from service technicians.[1]

EPA's requirements are similar to, although slightly different than, those adopted by California in the Omnibus Low NOx rule passed in August 2020. In contrast to the EPA's new rule, the California Heavy-Heavy Duty regulations increase in several steps in MY 2024, MY 2027, and MY 2031, and set different mileages for useful life. Per Section 177 of the Clean Air Act, the federal agency is expected to decide this year whether to grant California a waiver, thereby allowing both California's and the federal emissions standards to exist simultaneously or reject California's waiver request and impose a single national emission standard for such engines.

In one of the clearest signs yet that these air quality regulations and the move to ZEVs may trigger the sunset of diesel engine development, Navistar announced in July that its newest internal combustion engine for its North American portfolio would be its last.[2] Navistar joins their HD truck and bus competitor, DTNA, who declared the beginning of the post-internal combustion engine era with their announcement at ACT Expo in 2019 that "the future is electric."[3] Many light-duty (LD) and MD manufacturers, such as GM and Volkswagen, have already laid a path with goals to sunset combustion that most HD OEMs are expected to follow soon.

> **Leading HD manufacturers** have begun to announce the **sunset of or transition to post-internal combustion** engines for vehicles in North America and there is speculation that more announcements will come.

ZEV mandates march on within states, spread to new states and fleet types

California's aggressive ZE regulations continue to advance in the state and nationally. In late 2022, details on the ACF rule and timing of its passage crystalized. The ACF will require large fleet owners to purchase and operate ZEVs, steadily increasing the proportion of their rolling assets to ZEVs until reaching 100% between 2035 and 2042 (final compliance date varies by application). Private sector and broker fleets with more than $50 million in gross revenue nationwide or 50 vehicles across the country with at least one that enters the state within a calendar year will have the option to begin purchasing ZEVs exclusively starting in 2024 or meet certain milestones

> California's ACF rule will require large fleet owners to steadily increase their use of ZEVs until **reaching 100% between 2035 and 2042**.

for converting segments of their fleet based on body type. Fleets choosing the so-called "Milestones Pathway" must voluntarily waive their rights under SB1, which sets useful life for vehicles, and can continue to purchase diesel and gasoline vehicles as long as ZEV targets are met.[4]

Drayage, state, and local government/ municipal fleets will be under their own accelerated requirements when the ACF rule passes. Starting January 1, 2024, all new trucks registered in the Drayage Truck Registry must be ZE with a goal to transition all Class 7-8 trucks operating at California intermodal seaports and railyards to full ZE by 2035. Public sector fleets will be required to purchase ZEVs for 50% of 2024-2026 model years and 100% of 2027-plus model years. It applies to cities, counties, special districts, state agencies, and entities with exempt plates from the DMV, but not certain federal, military, emergency, school, and most transit fleets.[5] The California Air Resources Board (CARB) approved the ACF rule at the April 27-28, 2023, meeting.

ACF adoption by other states is expected to follow a pattern reported in last year's Market Brief of consideration by states of a ZEV sales mandate for vehicle manufacturers.[6] The ACT rule, passed by CARB in 2020, requires original equipment manufacturers (OEMs) of MD and HD commercial vehicles to rapidly increase the sale of ZE trucks and buses during the next two decades. At the time of publishing the Market Brief last year, 11 other states and the District of Columbia were considering or had adopted the rule. Since then, Vermont passed their version of the ACT rule and North Carolina has begun considering its own version.

A memorandum of understanding (MOU) signed by 17 states and the District of Columbia setting a goal of 100% ZE sales for MD and HD vehicles by 2050 maps to the proliferation of California ZEV mandates to other states. The U.S. jurisdictions that signed the MOU collectively represent 43% of the population, nearly half of the economy, and 36% of the nation's MD and HD vehicles.[7] These states are taking their mandates further by targeting specific fleet types. In the past year, New York passed a requirement for all new school buses purchased to be ZE by 2027, and Hawaii, Oregon, and Massachusetts are targeting state-owned vehicles with 100% electrification mandates.[8,9]

> ACF adoption by other states is expected to follow a pattern reported in last year's Market Brief of **consideration by states of a ZEV sales mandate for vehicle manufacturers**.

Funding reaches historic highs for the next five years, targets ZEV market

Public incentive funding has played a historic role in building the market for clean technologies, but the amounts have never reached such highs. Last year's Market Brief first reported an uptick from a historic average of $3 billion annually following the passage of the IIJA of 2021.[10] Since last year, the IRA was passed by the federal government, which added tens of billions of dollars in additional funding to support the clean vehicle and infrastructure market. In addition, funding commitments have been increased in California and within a handful of other states, thus driving up the average annual funding that will target the clean fuel market to approximately $32 billion on average per year during the next four to five years (Figure 1).[11]

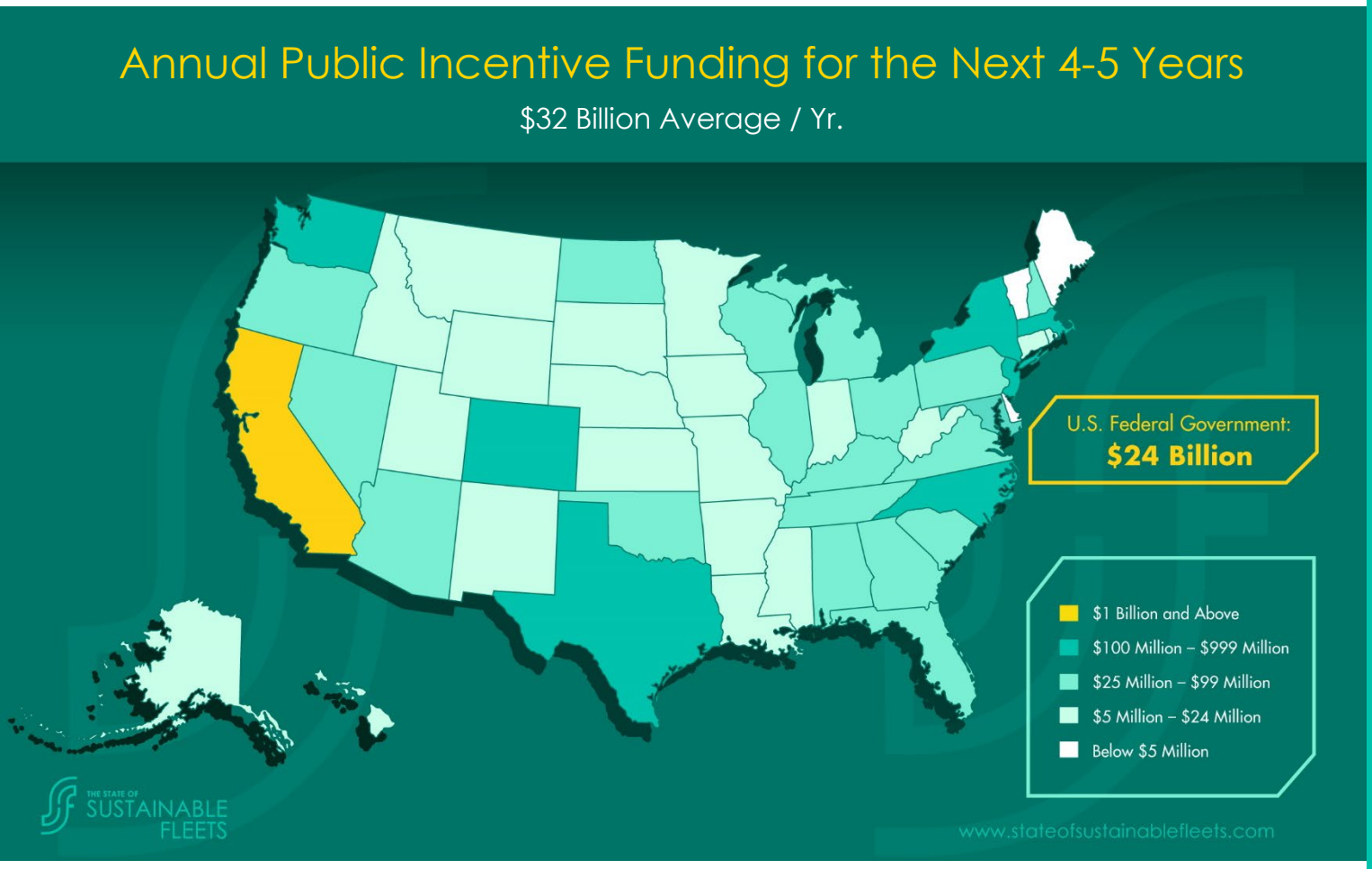

Figure 1: Annual funding for clean fuel and vehicle technologies for the next 4-5 years averaged by state and nationally. Includes state, local, utility, and federal incentive programs.

The IRA is the heart of this increase and is considered by most to be the largest investment ever by the U.S. government in climate action, with its strong focus on

> The IRA is considered by most to be the largest investment ever by the U.S. government in climate action with its strong focus on **building the market and infrastructure for ZEVs**.

building the market and infrastructure for ZEVs.[12] The IRA extends the LD ZEV tax credit with a cap of $7,500 for vehicles under 14,000 lbs. and creates a new tax credit with a cap of $7,500 for vehicles under 14,000 lbs. and creates a new tax credit up to $40,000 for MD and HD vehicles more than 14,000 lbs. through 2031. It also creates a $1 billion Clean Heavy-Duty Vehicles grant and rebate program to fund Class 6-7 ZEVs. Another $3 billion is dedicated to the purchase and installation of ZE port equipment or technology. These join funding programs previously created by the IIJA that are designed to build the infrastructure and supply chain for ZEV technologies with an $8 billion investment to develop regional hydrogen hubs and another $5 billion to states designed to establish a national network of public charging and supporting infrastructure for BEVs.[13,14]

A growing number of utilities are committing their own capital to infrastructure for charging, with many investments targeting fleets. In the past 18 months, programs by Colorado's Xcel Energy, Nevada's NV Energy, Illinois' ComEd, and Michigan's DTE Energy join California and New York utilities that previously dedicated nearly $1.5 billion for vehicle electrification infrastructure programs. A growing number of these "make-ready" programs target fleets with incentives that can cover up to 100% of the cost associated with preparing a site for EV charger installation.

Although ZEVs are beneficiaries of the lion's share of new funding, funding for near-zero-emission vehicles (NZEVs) and newer diesel engines remain an important part of many fleet sustainability programs. For the first time in nearly a decade, the AFTC that benefits propane and CNG operators was approved for a multi-year extension.[15] It provides a $0.50 per gasoline-gallon equivalent (GGE) tax credit for CNG and $0.36 rebate for propane fuel, plus an additional benefit of a 30% or up to $100,000 investment tax credit for infrastructure.

The Volkswagen Mitigation Fund will provide up to $300 million annually in funding, a figure that will decline each year until it expires at the end of 2026, for a variety of cleaner technologies, including newer diesel vehicles and NZEVs. Finally, the National Diesel Emission Reduction Act, known as DERA, also funds multiple technologies and was reinfused with another $60 million total and extended through 2031 with the passage of the IRA. Although these incentives remain beneficial to generate a return on investment in making the transition to clean technologies, mature technologies such as propane and CNG have demonstrated a positive total cost of ownership (TCO) without public incentive support in many applications as reported last year.[16]

California low carbon credit market plummets while new federal program will provide new credits

California's LCFS market has underpinned the deployment of clean technology in the state for the past decade. The program creates a marketplace for technologies that generate credits based on carbon-equivalent emission reductions produced by the full lifecycle of the fuel or energy source. While the program continues creating demand for investment in new technology, the increase in supply of several low carbon fuels — including RD, RNG, and electricity — has steadily eroded the price of credits for the past two years (Figure 2). In 2022, the decline accelerated, with the price of an LCFS credit dropping 44% after decreasing only 10% or less in the prior two years. Credits averaged $99.66 per metric ton (MT) in 2022 and dropped as low as $56.10/MT in late October, a significant decline from the peak of $219/MT in February 2020.[17,18] Type 1 credit transactions in 2022 amounted to more than $560 million, while total transactions exceeded $3.7 billion, approximately $800 million short of the market's value in 2021 despite a 24% increase in credit volume.

> Credit prices on California's Low Carbon Fuel Standard (LCFS) market **dropped 44% in 2022 to as low as $56.10/MT** in late October.

Two developments at the turn of the year may offer added benefits to clean technology adopters. At the beginning of 2023, Washington joined Oregon as the only other state besides California with a market akin to the LCFS. By the end of January, Washington officials disclosed that 23 entities had registered to purchase credits and 41 entities had registered to generate credits with clean technologies. With this addition, the entire West Coast of North America (California, Oregon, Washington, and British Columbia) has active low carbon credit markets. Beyond the West Coast,

California Low Carbon Fuel Standard Credit Volumes and Prices (2015-2022)

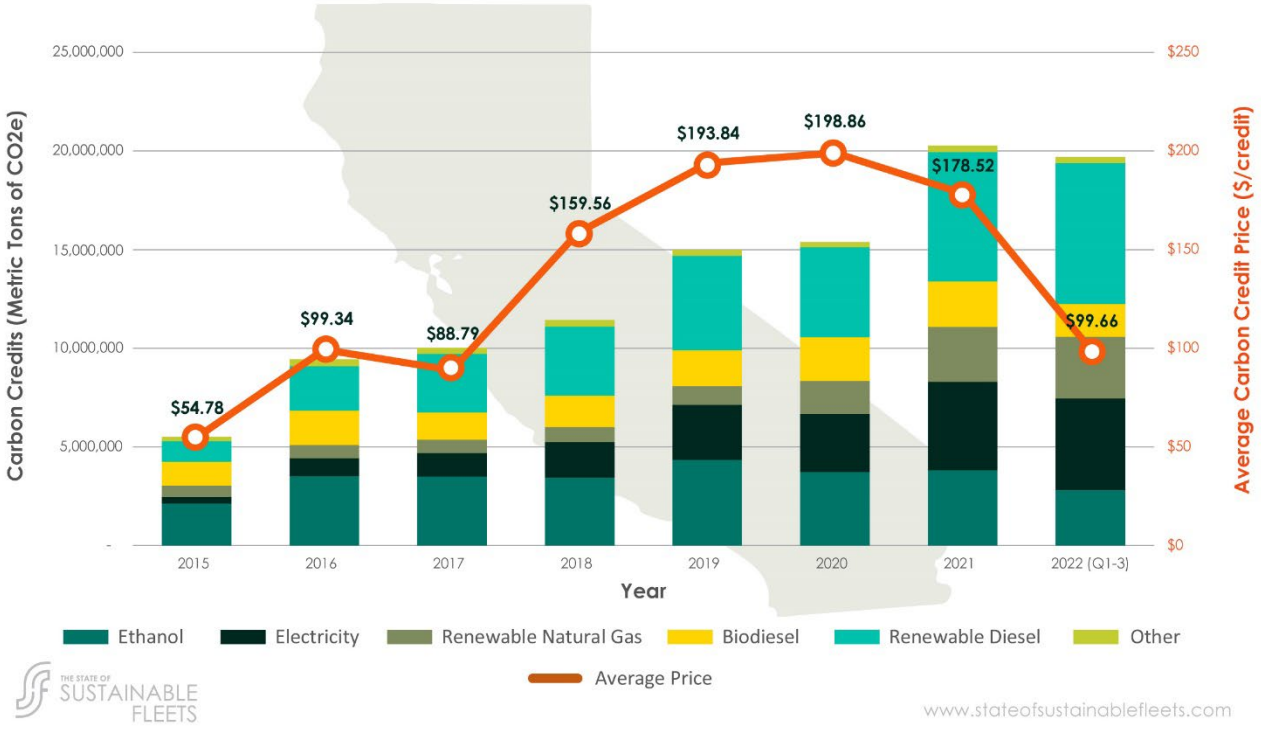

Figure 2: Summary of credit transaction data published by California Air Resources Board. Credit volumes cover the period of Q1 2015 through Q3 2022, while credit prices cover the period of Q1 2015 through Q4 2022. In 2019, the pricing scheme expanded from a single price type to three price types. This analysis accounts for Type 1 prices which are sold on the "spot" market, where the transaction takes place within 10 days from the sale agreement. In the second half of 2022, the average Type 1 credit price was $78.43.

other states have been looking at adopting similar programs, including Minnesota, New Mexico, and New York. While these states have all introduced state bills to create their own programs for several years, they remain stalled.

Another new development could help reduce the cost of LD vehicles and, if revised to extend to MD and HD vehicles and fleets, could offer a new benefit for Class 4-8 ZEV adoption. On November 30, 2022, the EPA released a proposed rulemaking under the Renewable Fuel Standard (RFS) program to generate credits — called "eRINS" (Renewable Identification Numbers) — from electricity produced from RFS-eligible biomass-based fuels, including biogas. The current version of the framework designates manufacturers of LD vehicles as the parties eligible to purchase renewable electricity and generate credits based on the estimated electricity consumption for that OEM's EVs, both new and previously sold.[19] The current draft does not include MD or HD vehicles, nor an opportunity for fleets and infrastructure providers to take part directly. Stakeholders provided feedback during the public comment period encouraging EPA to extend benefits of eRINs to heavier vehicles and to fleets. The rule is expected to be finalized by the EPA by mid-June and take effect in late 2023, with the first generation of eRINs to be allowed January 1, 2024.[20]

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Diesel and Gasoline Vehicles

Stringent air quality regulations help trigger the sunset of diesel engine investments

Diesel technology has dominated MD and HD markets for more than a century and will continue to lead in the near term. However, EPA's new Clean Trucks Plan may have effectively set 2027 as the sunset year for new diesel engine development programs by North America's HD engine OEMs. Released in December, the new thresholds for diesel engine NOx emissions are more than 80% lower than current standards and must be met through new, rigorous testing procedures.[21] The designs required to meet these standards, as well as the longer useful life and warranty periods that the rule also defined, are expected to raise the cost of a new Class 8 tractor up to $30,000, while likely requiring additional ongoing maintenance from service technicians.[22]

The new federal rule joins a growing web of regulations that will increase the complexity and cost for manufacturers and their customers. EPA's ruling was issued approximately one year after CARB's Heavy-Duty Low NOx Omnibus (Omnibus) and ACT rules took effect. The EPA has yet to respond to the state's request for a waiver to enforce its Omnibus rule, which places similarly strict emissions, warranty, and useful life requirements on engine and vehicle providers. Both rules could coexist with slightly different timeframes and thresholds, establishing a new, complex landscape in which to build, sell, and operate diesel engines and vehicles. As one Cummins representative noted, "Complying and participating in various points systems is requiring providers to develop technology and deployment strategy simultaneously, absorbing more time and resources than is typically required for new technologies."[23]

> EPA's new Clean Trucks Plan may have effectively **set 2027 as the sunset year for new on-road diesel engine development** by North America's HD engine OEMs. Diesel production and sales will continue for some time after.

Manufacturers are paying close attention to state and federal regulations. In 2019, DTNA signaled it would begin its move to the post-internal combustion era with a shift to an electric future.[24] This past July, Navistar revealed its newest internal combustion engine (ICE) and stipulated that it would also be Navistar's last engine in the diesel family for the North American market.[25] Traton SE, parent company of Navistar, re-directed research and development funds from its petroleum products to increase investment in its battery-electric initiatives by almost 50% in anticipation of a 2030 production mix dominated by electric technology.[26] Diesel production and sales will continue for many years, but 2027 may become the sunset year for new diesel engine development by most manufacturers.

Gasoline and diesel prices reach historic highs while support for biofuels grows

Soaring petroleum fuel prices challenged fleet margins in 2022, prompting federal attention. Russia's ongoing war in the Ukraine, U.S. inflation, and a reduction in domestic refinery capacity drove up the average price-per-gallon of gasoline and diesel by 41% and 56%, adding $0.80/gal and $1.50/gal to fueling bills, respectively.[27] At their high point in late June, national average prices reached $4.79/gal gasoline and $5.78/gal diesel.[28,29] Compared to 2020, pump prices were up 80% for the year overall.[30]

The federal government explored several measures to moderate these spikes, including waiving the summer ban on E15 blends and proposing a gas tax holiday.[31,32] These steps overlapped with commitments to transition the U.S. transportation and energy sectors to 100% carbon-free solutions and away from the fossil fuels that dominate road transportation today. In August, the IRA allocated billions of dollars to low- and no-carbon fuels and transportation technologies. Incentives included a Clean Fuel Production Tax Credit for low-carbon transportation fuel sold between 2025 and 2027, and extending a $1 per gallon of biodiesel- and/or renewable diesel-blended fuel tax credit through 2024, as well as a $0.50 per

gallon of eligible alternative fuel tax credit, and a refueling property tax credit extension through 2032.[33] Committing to these incentives for multi-year periods was an important first and enables fleets to project costs further ahead than previous one-year programs and extensions allowed.

Biofuels faced comparable price increases as conventional diesel, but many fleets report a preference for the renewable option in cases where prices are at or near cost parity. On average, national B20 blend prices followed diesel's trajectory, with average annual prices increasing by approximately $1.44/gal, offering fleets about 5% savings compared to diesel on a per-gallon basis. Meanwhile RD saw a year-over-year incremental of $2.24/gal, reaching $5.91/gal for the year on average.[34] Fleets surveyed for this report that use RD report paying a diesel-equivalent or better price for it where they can get it. Most fleets using it are in California, where the state's LCFS program supplies a financial incentive to use low carbon fuels and where taxes contribute to higher-than-average diesel prices. The average diesel price reported by the California fleets surveyed was 18% higher than the national average.[35]

> Rising petroleum prices posed a major threat to fleet margins in 2022. **Gasoline and diesel prices shot up by a staggering 41% and 56% per gallon**, respectively.

Big efficiency gains still available to most fleets, though leading adopters reach a plateau

While the Federal Highway Administration (FHWA) reported an average fuel economy of 6.24 mpg for over-the-road tractors in 2020, the North American Council for Freight Efficiency's (NACFE) 2022 Annual Fleet Fuel Study recorded an average fuel economy of 7.23 mpg from 24 fleets that have been using and reporting on efficiency technologies and practices for more than a decade.[36] NACFE's data indicates that fleet use of efficiency technologies and practices continues to grow, contributing to the improved fuel economy. In 2021, the 24 fleets used 41% of the 86 efficiency technologies and practices in the study with their Class 8 tractors, recovering their 2016-2017 highest adoption rate. Trailer skirts, automated transmission, and lower viscosity engine oil were three of the most common solutions contributing to an average annual fuel cost savings of approximately $5,000 per truck.[37,38]

Fuel economy only improved 1.1% between 2017 and 2021 for the early adopters in one study, down from a per-year improvement rate of 2% between 2011 and 2017.

Nearly 70% of fleets with more than 1,000 vehicles used efficiency technologies and practices in the last two years. By contrast, **only 42% of fleets with fewer than 1,000 vehicles** report use in the annual survey.

While the use of efficiency technologies and practices is growing, the gains for leaders have plateaued. Fuel economy only improved 1.1% between 2017 and 2021 for the early adopters in NACFE's study, down from a per-year improvement rate of 2% between 2011 and 2017.[39] Recent behavioral shifts are negating some of the fuel economy gains, NACFE suggests.[40] As consumer demand spikes have collided with a persistent driver shortage, fleets have reduced their use of 65 mph speed limiters from 80% in 2017 to 62% in 2021, sacrificing approximately 0.1 mpg for each mph over 65. Terminal congestion has also forced drivers to idle longer, and the rising cost and limited availability of trucks (new and used) have caused fleets to extend their typical replacement cycle and hold onto older, less-efficient vehicles for longer.[41]

While early adopters are seeing slower gains, significant fuel economy savings are still available for most fleets driving on U.S. roads. This year's State of Sustainable Fleets survey found that only 48% of responding fleets have used efficiency technologies or practices in the last two years, despite years of development, deployment, and proven cost benefits. Shuttle and yard truck fleets reported the greatest use rates (61% each), followed closely by regional- and long-haul logistics fleets (57% and 58% respectively). Altogether, recent data shows an estimated 16% improvement in fuel economy is available to most U.S. tractor operators today.[42] Beyond this point, gains are closely tied to driver behavior.

Responses to the State of Sustainable Fleets survey indicate that small fleets likely have the most to gain from adopting vehicle efficiency technologies and practices. Nearly 70% of fleets with more than 1,000 vehicles used efficiencies in the last two years. By contrast, only 42% of fleets with fewer than 1,000 vehicles report use of efficiencies in the annual survey. Whereas cost and access can be significant barriers to clean fuel adoption for some fleets, efficiency investments offer a cost-effective and accessible path to emissions reductions.

Today's newest diesel engines offer significant efficiency gains for HDVs, particularly for fleets that operate vehicles more than eight years old. Initial data from MY2022 deployments shows Class 8 trucks achieving between 7.5 and 9.6 miles per gallon — even 10 mpg under certain conditions — indicating that a single truck can meaningfully improve fleet-wide efficiency. In 2023, results from five projects awarded under SuperTruck 2 are expected to reveal areas where manufacturers may continue to make improvements. However, this is the last year that SuperTruck will inform diesel truck research and development. In late 2021, the DOE's awards under SuperTruck 3 supported 5 projects for ZE technologies and signaled that future awards will likely benefit ZEVs.[44]

RD production doubled in 2022 and industry investments support additional growth

Supplies of RD, a drop-in replacement for petroleum-based diesel, grew 44% in 2022, even as imports dropped, due to a sharp rise in domestic production. Domestic RD production grew at least two-fold, from more than 600 million gallons in the first 10 months of 2021 to 1.2 billion gallons during the same period in 2022, accelerating from its earlier year-over-year growth rate of 30%.[45] The industry expects to reach its 5-

> **"US Foods successfully converted 100% of the fleet fuel used at all of our California broadline distribution centers to renewable diesel fuel and we look forward to expanding these efforts."**
>
> – **Ken Marko**, Fleet Sustainability Senior Manager, US Foods

billion-gallon capacity target in 2024, one year ahead of schedule.[46] EPA helped accelerate the market by approving canola oil as a pathway to meet the 50% lifecycle greenhouse gas (GHG) emissions reduction target under the RFS.[47] This expands producers' feedstock options and benefits canola-growing states such as Montana.

Energy majors are using their influence and investments to further boost the RD market. Marathon Petroleum and Neste launched a joint venture to support Marathon's work converting a petroleum refinery in Martinez, California, to produce biofuels starting in early 2023 and reaching full capacity (730 million gallons per year) by 2024.[48] Phillips 66 announced plans to open an 800 million gallon-per-year biofuel facility near San Francisco by 2024, and Shell was contracted to supply Penske Truck Leasing's 32 California fueling sites with RD.[49,50]

Survey results indicate that demand is growing along with supply. For the first time since State of Sustainable Fleets was launched in 2020, more fleets reported using RD than BD (27% compared to 26%), and demand from surveyed private fleets rose from 18% to 26%, matching the average demand of public-sector fleets. Specifically, more than 35% of regional-haul, long-haul over-the-road, and refuse fleets used RD in the last two years, mostly in states with active low carbon fuel programs. The value proposition of reducing GHG emissions with a drop-in diesel alternative at or near cost parity further stimulated demand: national RD consumption increased by more than 45% for the second year in a row, rivaling BD consumption for the first time. In California, RD made up 83% of all bio-based diesel consumed in transportation in the first three quarters of 2022 according to LCFS data.[51]

Looking ahead, RD markets will continue to be strongest in states where low carbon fuel programs help lower the per-gallon price to meet or compete with diesel. Yet, as California demonstrated in 2022, the balance of supply and demand is essential for these programs to steadily support

> Domestic **RD production doubled**, soaring from 600 million gallons in 2021 to 1.2 billion in 2022.

supply growth. During the last 18 months, California's LCFS credit bank has ballooned as the supply of credit-earning fuels, including RD, has increased, driving credit prices as low as $56/MT— about one-fourth of the market high of $219/MT in 2020 (Figure 2, Policy and Funding chapter).[52] Several renewable fuel industries are facing higher operating costs, and without the support of strong LCFS revenues, stakeholders observe that the growth trajectory for RD may slow down until prices recover to at least $125 per credit.[53] Amendments to the LCFS program are in the works this year, and while actions are expected to address the price drop, program officials have indicated that the rulemaking process could extend into mid-2024.[54]

BD demand and federal support hold steady, production declines slightly in 2022

BD has been an important part of U.S. fuel supply for decades due to blending mandates, though it is only certified for use in diesel engines at up to 20% blends. The transportation sector's use of RD and BD in California as a share of diesel consumption

> **"Combined with Ruan's fuel additive program, Ruan effectively runs various biodiesel blends through the winter, even in colder climates."**
>
> – **Steve Larsen**, Manager – Fuel, Ruan Transportation Management Systems

grew from 37% in 2021 to 45% in 2022 with most of the growth coming from increased use of RD.[55] As reported last year, the Intergovernmental Panel on Climate Change forecasts that renewable fuel consumption in the U.S. must increase five-fold to achieve the Paris climate targets globally.[56]

While 2022 saw several BD refineries close or convert to produce RD, resulting in a slight (approximately 2%) drop in total domestic production from 2021, support from important energy majors remains steady and innovation continues.[57] In 2022, Chevron partnered with Texas A&M researchers on a five-year, multi-million dollar "diesel nut" project to create a production-light peanut with above-average oil yields for a biodiesel feedstock.[58] The company also completed its acquisition of Renewable Energy Group, one of the largest BD producers in the U.S. by volume and expects BD to be an important part of its production target of 100,000 barrels of renewable fuels per day by 2030. Optimus Technologies received approval from California to pilot its advanced fuel-system technology that enables diesel engines to operate on 100 percent biodiesel (B100) on MD and HD vehicles and will test run with Valley Pacific Petroleum's fleet.[59]

Fleets and fuel providers expect BD to remain a part of the commercial fuel mix over the mid to long term. More than a quarter of the surveyed fleets use blends of 2% and 20%, but use is concentrated in larger fleets and specific applications. Logistics fleets reported the highest adoption rates (38%) followed by shuttle fleets (35%). Fleet size is significant: 30% or more of fleets with greater than 1,000 vehicles reported using BD blends while only 8% of fleets with fewer than 100 vehicles use this fuel.

Funding and regulation motivate many fleets to adopt clean technologies

Interest by fleets who have not yet begun testing or adopting the leading clean drivetrain technologies is now approaching the same level as their early adopter peers. In this year's fleet survey, 75% of fleets that have not yet begun testing or adopting

propane, CNG, or battery-electric or fuel cell electric vehicles expect their use of clean vehicles and fuels will grow in the next five years. In the past four years of the annual survey, including this year, 83-85% of fleets who have piloted or adopted one or more of these drivetrains plan to grow their use of them.

Vehicle price leads by a notable margin among barriers to adoption cited by these fleets that are now considering alternative, clean drivetrains for the first time. The vast majority, 83%, of these fleets cite vehicle price as a barrier followed by vehicle availability and infrastructure costs tied with 63% citing these as barriers in the survey. Insufficient fueling infrastructure (52%) and fuel availability (43%) round out the top five barriers, according to these fleets. While numerous studies and fleet testimonials, including this one, demonstrate real cost, performance, and operational benefits for many fleets who overcome these barriers to adopt clean technologies, many non-adopters remain unmoved until recently.

Incentives availability and regulation are the number one and two reasons cited by non-adopters to begin using clean drivetrains.

Incentives availability and regulation are the number one and two reasons cited by non-adopters to begin using clean drivetrains. These non-adopters are tracking the dramatic rise of funding for clean vehicles and infrastructure, stringent new diesel emissions requirements, and state-level ZEV mandates. It is notable that diesel emissions standards are expected to increase diesel vehicle costs while funding provides a subsidy to adoption, reducing the gap with clean vehicle prices and thereby addressing the top barrier to adoption cited by these fleets. Improved vehicle availability, changing customer expectations, and improved TCO benefits round out the top five motivators of these fleets to begin adoption soon.

Industry Perspective – Diesel Technology Forum

What's the future for diesel in trucking? While a growing number of ZE truck options are emerging, the nation's trucking fleet continues to be dominated by diesel power, a trend we expect to continue for a decade or more. Last year, 2022, was a banner year for new Class 8 trucks investments: more than 300,000 units sold.[60] More than 97% of those trucks were powered by advanced diesel engines.

At the end of 2021, 53% of all diesel-powered commercial trucks operating on U.S. roads were the newest generation (2010 and newer) that achieve near zero levels of emissions of particulates and nitrogen oxides.[61] Though exact year end data is not yet available at press time, if adoption trends of advanced diesels continue as in previous years, we expect that 56-58% of the current national fleet to be the newest generation diesel.

The next chapter for HD internal combustion engine technology is now written, thanks to EPA's Cleaner Trucks Initiative. Issued in December 2022, the new final rules requiring further cuts in emissions and expanded emission warranty coverage for 2027 and later MY diesels. In just four years, the new generation of diesels will be even nearer to zero emission, going from today's levels of 0.02 g/BHP-hr to 0.035 g/BHP-hr. To meet these new lower levels, manufacturers are expected to use a range of strategies, including more efficient exhaust aftertreatment systems, enhancing combustion, and other approaches. Other new rules coming into effect will lower GHG in the next three to five years, further boosting fuel efficiency for fleets choosing to invest in those new trucks.[62]

While fleets have a growing number of fuel and technology choices to green their operations, many experts agree that advanced diesel engines — particularly using renewable fuels — will provide an available and affordable option to meet corporate and climate goals in the future.[63] Trucking companies that are invested in diesel today can continue to leverage those investments in the future, while doing better for the environment and their pocketbooks.

Significant growth is expected in supply of BD and RD in coming years, with a range of new refinery investments on the West Coast and Gulf Coast of the U.S. New feedstock supply streams from innovative cover crops are also being explored. According to the U.S. Energy Information Administration, imports of biodiesel will grow to 46,000 barrels per day and U.S. production of biodiesel will grow to 115,000 barrels.[64]

The benefits of using RD were underscored in a recent study that evaluated options for commercial truck fleets in the heavily traveled Northeast corridor.[65] The study found that, compared to a full electrification strategy between now and 2032, three times the reduction in carbon dioxide emissions can be achieved at 25% of the cost by accelerating the turnover of older trucks to new advanced technology diesel models and utilizing low-carbon RD and BD across the entire fleet.

All opinions in the above Industry Perspective represent the opinion of the aforementioned organization and do not reflect the opinions of Gladstein, Neandross & Associates (GNA) or the report sponsors

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Propane Vehicles

Propane engines offer path to near-term compliance with emission standards

Propane engines on the market today already meet the stringent new engine emissions levels of EPA's Clean Trucks Plan and California's Low NOx Omnibus. Roush's Gen 5 engine for Blue Bird's school buses and Cummins' B6.7L engine for MD applications, the first from a major diesel engine manufacturer, are both already certified to the 0.02 g/bhp-hr NOx standard.[66] In 2022, Blue Bird became the first vehicle manufacturer to achieve EPA's 2022 HD refueling standard for both gasoline and propane school buses.[67] As a purpose-built direct-injection propane engine, Cummins expects the B6.7L to emit between 15% and 30% less carbon dioxide than repurposed gasoline engines, which are fairly common in the propane vehicle market.[68]

THE FLEET TYPES LEADING PROPANE VEHICLE ADOPTION

Fleets leading adoption of MD and HD propane vehicles and approximate vehicles in operation.

DELIVERY | SCHOOL | SHUTTLE | MUNICIPAL | PUBLIC UTILITY

Estimated Medium- and Heavy-Duty Vehicles in Operation

TENS OF THOUSANDS — THOUSANDS

As fleets seek to comply with EPA's Clean Trucks Plan, the industry anticipates an increase in propane vehicle uptake in the mid-2020s due in part to the limited supply and high cost of the BEV options that otherwise compete for adoption in school, municipal, and paratransit services. Among surveyed fleets using propane

vehicles, 57% plan to increase their propane consumption during the next five years, primarily in municipal and school bus service. However, it is possible that the longer horizon for propane lies with rural and off-road operations outside of so-called ZEV states.

> Roush's Gen 5 engine for Blue Bird's school buses and Cummins' B6.7L engine for MD applications are both already **certified to the 0.02 g/bhp-hr NOx standard**.

Propane price remains well below gasoline with a tax credit extension

The price of propane at private stations increased for the second year in a row, rising 15% from the 2021 average to $2.10 per GGE due in part to an increase in petroleum prices and an approximately $0.15-per-gallon increase on transportation and distribution fees.[69,70] This did not significantly undermine fuel cost savings for fleets compared to gasoline: On average, fleets using private stations saved $1.94 per GGE.[71] Fleets surveyed for this report cited similar price benefits and saved $1.54 per GGE, on average, using a mix of private and public fueling.

The newly extended AFTC provides a tax credit of $0.36 for propane along with a 30% tax credit or up to $10,000 for fueling infrastructure investments through 2024. This was the first time in nearly a decade that EPA has extended these credits for more than a 12-month period, enabling fleets to plan further ahead.

Vehicle sales rise, carried by paratransit and service, while heavier vehicles enter market

After two years of declining sales, industry reports indicate that sales of new propane vehicles increased 11% overall in 2022 thanks to a surge in demand for MD paratransit, municipal, and utility vehicles, which offset a drop in school bus sales.[72] Delivery vehicle sales also increased by approximately 40%, mostly in package and beverage delivery services. Public funding program records indicate that many of these vehicles are serving fleets in the Central and Eastern U.S., where propane is widely available and the cost of switching to an even lower- or zero-

After two years of declining sales, industry reports indicate that **sales of new propane vehicles increased 11% overall** in 2022 thanks to a surge in demand for MD paratransit, municipal, and utility vehicles.

emission fuel, such as electricity, remains out of reach.[73] The Propane Education & Research Council (PERC) observes that propane is favored in the paratransit segment, which requires long-range vehicles to support unpredictable routes, as many fleets operate on an on-demand basis.

Although more propane-fueled HD school buses were sold than in any other individual propane vehicle category in 2022, sales were down about 46%. Supply was one reason: In 2022, Thomas Built re-structured its portfolio to prioritize battery-electric options and phase out its propane-fueled buses starting in 2023. Competing technologies also had an impact. Sales of natural gas school buses increased by 35% thanks to revisions in federal funding programs that made the fuel eligible in EPA's Clean School Bus Program. Local and federal mandates also pushed districts to electrify, and these fleets may be pursuing BEVs where there are funding opportunities. More details are provided on these technologies in their respective chapters.

Propane remains a strong option for many school districts, particularly in rural and underfunded areas where federal funding can support propane bus purchases across the U.S. The EPA's 2022 Clean School Bus Program awarded funds for 109 propane buses primarily located in rural, tribal, and low-income districts. Several awards were made in the states of Iowa, Michigan, Minnesota, Ohio, and Pennsylvania.[74]

Leveraging funds from the IIJA, the Federal Transit Authority awarded more than $18 million to replace diesel and gasoline transit vehicles with propane alternatives in Massachusetts, Minnesota, North Carolina, South Dakota, and Michigan.[75] Several of these grants also supported BEV deployments with the same agencies, indicating that fleets find value operating propane vehicles alongside the newer and less proven ZE models. Federal support

"Propane is a cleaner burning fuel with lower cost maintenance and great industry and public purchasing incentives and fuel rebates. It has been a game changer for our school district."

– **Kay Cornelius**, Transportation Director, St. Louis County Schools

may be in recognition of propane's benefits in rural areas where limited finances and fueling resources can be a barrier to adopting other emission-reducing technologies.

The off-road sector faces lower pressure to reduce emissions than most on-road applications. Cummins' B6.7L engine is a strong candidate for off-road fleets looking to reduce their emissions footprint in applications such as yard trucks that require heavy, long-life designs. However, adoption in its first year has been low, with some vehicle manufacturers ultimately declining to offer it due to a lack of customer demand.[76] In September, MAFI revealed a propane yard truck design using PSI's 8.8L engine and reported a demonstration with the Port of Newark Container Terminal and a sale to serve the Port of Long Beach.[77,78] While more models are forthcoming from other manufacturers by mid-decade, according to PERC, it remains to be seen whether adoption will climb.

> **"In March 2023, we began using rLPG instead of petroleum propane. We've found rLPG vendors very easy to work with in implementing the new supply and look forward to the market expanding."**
>
> – **Craig Beaver**, Administrator for Transportation, Beaverton School District

Renewable propane fuel use by fleets remains low while supply and blending options are uncertain

As RD production increases, supplies of its byproduct, renewable propane (rLPG), will also grow. However, according to the National Renewable Energy Laboratory (NREL), this growth is likely a decade away because the incentive for producers to sell the product to transportation end users is unclear.[79] As explained in the previous two Market Briefs, market conditions such as the size of the market and the value that RD producers can secure for other uses such as on-site use, sale to other markets like heating, or lowering the carbon intensity (CI) of RD for sale in low-carbon fuel markets like California's LCFS will determine whether this technology can scale and how quickly.

Dedicated rLPG projects may supply fleets in the near-term. Global Clean Energy Holdings and AmeriGas partnered in 2022 to develop a 13-million-gallon capacity rLPG production facility in Bakersfield, California.[80] Production will begin in early 2023, although the volume of fuel sold to fleets was not disclosed.

While examples like the Bakersfield rLPG plant and U-Haul's 2021 purchase of a million gallons of rLPG exist, most fleets still cannot access significant volumes of this renewable fuel.[81] Of the fleets surveyed for this report that use propane, only four report using rLPG and two of them used it for less than half of their fueling requirements. While this alternative can offer fleets GHG emission reductions, rLPG is unlikely to offer fleets an immediate strategy for deep GHG emissions reductions soon due to limited supply available to fleets.

> Only **four fleets that use propane are using rLPG** in the annual fleet survey, and two of them used it for less than half of their fueling requirements.

In addition to rLPG, fuel producers are exploring the business case for blending renewable dimethyl ether (rDME) into propane, but economic and legal barriers prevent significant commercial sales. rDME is a non-toxic gas produced from bio-based feedstocks that yields a lower CI than propane. At blend rates up to 20%, it can be used as a drop-in replacement for propane. Oberon began producing the first commercial volumes (5,000-6,000 gallons per day) of rDME in the U.S. in mid-2021, and Suburban Propane sold the first blends with 4% rDME to forklift fleets in June 2022.[82] Production is expected to grow this

decade, but there is almost no documented demand from over-the-road fleets due to the limited reduction in emissions at today's 4-20% blend rate and a lack of manufacturer plans to develop a compatible engine for higher rDME concentrations.[83,84]

Propane offers GHG cuts that may rival or benefit BEVs in some locations

Propane has proven its value as an accessible fuel source that can lower criteria pollutant emissions for fleets across the U.S. Its record for reducing GHG emissions, however, is not strong without renewable propane. At the tailpipe level, conventional propane cuts GHG emissions by 12% and 15% relative to gasoline and diesel, respectively.[85] While that reduction is smaller than any other clean drivetrain in this study, it can add up. In Colorado, USPS contractor Hi Pro reports that it avoids 281 MT per year of carbon dioxide (equivalent to 60 gas-powered passenger cars) by operating its Class 6 fleet equipped with Roush's latest propane engine rather than charging battery electric models on the local electric grid.[86]

GHG emissions are evaluated on a full lifecycle basis, including production and drilling, refining, distribution, use, and disposal (including vehicles and components). One industry report claims that fueling with propane can achieve lower lifecycle GHG emissions than grid charged BEVs in 38 states.[87] Such findings consider the source of electricity and disposal of vehicles and components, such as batteries, as this study did. However, comparisons between electricity and other energy types are highly dependent on the type of electricity produced in every given location and are notoriously rough at the state-level. Furthermore, battery disposal is still a nascent industry and any conclusions about emissions associated with their disposal at scale are highly speculative.

Three companies have developed charging products that feature propane as a cross-cutting energy solution. Pioneer Power Solutions Inc.'s mobile charger uses propane to generate electricity for vehicle

> **"Pittsburg USD has benefited from the use of use of propane in our school bus fleet. The propane was readily available and more cost effective than the diesel. The performance has been pretty close overall, with very little down time."**
>
> – **Matthew Belasco**, Director of Maintenance, Operations, and Transportation, Pittsburg Unified School

charging, and the company received three orders between Q1 2022 and Q1 2023.[88,89] Propane Fueling Solutions' EV Charging Skid uses wind turbines, solar panels, and a propane generator to produce 60 kW charging rates for BEVs, and propane vehicles can also fuel with the on-site propane tank.[90] The company has one customer order and 12 units in demonstration. Finally, EV Power Pods' gas-powered direct-current fast charger products can run on propane, natural gas, or their renewable variations.[91] Its first units were in production at the end of 2022.[92] These technologies offer creative solutions to secure energy for the operations of fleets with site constraints or electricity supply concerns and they may even offer an added pathway to GHG reductions for fleets on a lifecycle basis in some locations.

Industry Perspective –Propane Education and Research

Fleets have relied on propane autogas as a powerful, low-emission energy source for years. Best known as the leading alternative to diesel in the school bus market, there are more than 22,000 propane autogas school buses providing

children in more than 1,000 school districts a safe and healthy ride to school. As part of the near-zero-emission alternative fuel options available for funding in the EPA's Clean School Bus Program, propane autogas school buses offer significant emissions reductions at a fraction of the cost of battery-electric models. However, propane autogas' performance is not limited to school transportation — it continues to drive the Class 3-7 market with gains in paratransit, package, food, and beverage delivery.

Propane autogas is a clean, affordable, locally sourced, and reliable energy that is part of a wide path to a low carbon future. As the clean transportation industry moves away from conventional fuels, propane can provide powerful and reliable energy, alongside significant reductions in CO2, NOx, and particulate matter at a fraction of the cost to implement compared to other alternatives.

In engine technology, today's ultra-low NOx propane autogas engines are certified to 0.02 g/bhp-hr, which exceeds even the newest EPA guidelines for 2027+ model year vehicles. The Cummins B6.7 propane engine is coming to market and gaining interest of OEMs today. In testing, the Cummins B6.7 Propane engine delivered the lowest greenhouse gas emissions of any propane autogas-powered engine and will deliver some of the lowest GHG emissions in the MD market.[93]

The energy source itself is also changing. Propane can also be renewable. Renewable propane offers the same benefits as conventional propane — reliability, portability, and power — but with the added benefit of further reduced GHG emissions when compared with other energy sources. Made from a variety of renewable feedstocks such as vegetable oil, used cooking oil, yellow grease, animal tallow, and even oilseed crops like the camelina sativa, it can be used stand alone or in innovative blends with other renewable or low-carbon energy sources — including conventional propane — without expensive modifications or upgrades. In 2022, more than 4 million gallons of renewable propane were produced according to the EPA. With more production plants coming online in 2023, estimated volumes will increase to over 17 million gallons. The industry has a viable pathway to 100 million gallons in the next five years.

For most fleets utilizing propane autogas, private fueling remains the strategy of choice because it's affordable, scalable, and available today. It can be installed quickly in any location, including completely off grid. The industry is also meeting the ever-changing requirements in the transportation sector by marrying propane technology with other renewable

energies to address infrastructure and range challenges present in electric vehicle fleets. These solutions can be temporary or long term but allow for DC Level III charging as stand-alone and completely off the grid whenever and wherever they are needed.

Propane autogas not only enables significant fuel savings and emissions reductions but can also help fleets cut maintenance costs compared to current LD and MD diesel fleet vehicles. With a network of more than 700 premier autogas service locations nationwide, fleet managers can be assured minimal downtime for maintenance and repairs with propane autogas. These service centers are trained on the current autogas fuel systems and have access to the necessary OE or aftermarket parts to complete the repair.

To provide reliable power and reduce emissions, it will take a variety of clean energy sources working together to achieve that goal. The more diverse our energy mix is, the more reliable it is. As fleet owners look for ways to reduce their carbon footprint, renewable propane and conventional propane are ready to provide fleets with the clean power they need.

All opinions in the above Industry Perspective represent the opinion of the aforementioned organization and do not reflect the opinions of Gladstein, Neandross & Associates (GNA) or the report sponsors.

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Natural Gas Vehicles

RNG supply exceeds California demand while emissions drop

Expanded production from dairy and swine digesters continued to drive the CI of RNG in California further below zero. In October 2022, the CI of all RNG used in transportation was 78% lower on a year-over-year basis, breaking records in Q3 2022 at -111.70 gCO2e/MJ.[94] Data available from CARB shows that the average CI during the first three quarters in 2022 declined by 140%, from -38.44 gCO2e/MJ to -92.23 gCO2e/MJ. The share of production in the pipeline that is carbon-negative is growing and likely to drive down California RNG average emissions further — 59% of these projects use or plan to use dairy digesters that achieve a negative CI.[95]

THE FLEET TYPES LEADING CNG VEHICLE ADOPTION

Fleets leading adoption of MD and HD CNG vehicles and approximate vehicles in operation.

REFUSE | PUBLIC UTILITY | REGIONAL | LONG-HAUL | TRANSIT | CARGO | MUNICIPAL

Estimated Medium- and Heavy-Duty Vehicles in Operation

TENS OF THOUSANDS — THOUSANDS

At the same time, the RNG supply continued to exceed demand in California. While RNG consumption in the state's transportation sector for RNG exceeded 88 million DGE in the first two quarters of 2022, conservative estimates find that the supply of RNG available for the transportation sector at that time was

at least twice as much.[96,97] Fleets demonstrated a ready need: During the calendar year, fleet use of natural gas in California continued to displace nearly all fossil-based CNG with approximately 95% of fueling needs being met with RNG for the second year in a row.[98]

In Q3 2022, the **CI of all RNG used in California transportation broke records**, plummeting to -111.70 gCO2e/MJ - a remarkable 78% year-over-year reduction.

Growth in RNG supply tapers while price and market developments introduce uncertainty

While data for full-year 2022 is limited, public records suggest that national RNG supplies may be tapering after several boom years. Conservative estimates suggest that RNG supplies approached 900 million DGE nationally in 2022 and that production will continue to grow, though at a slower pace than in the previous two years. As of mid-2022, more than 500 projects were either producing or planning to produce renewable fuel for the transportation sector in 48 states, representing a 217% growth from the reported project count in 2020.[99] However, by year-end, several projects had pushed their production launch into 2023, while public records showed that the number of RNG facilities due to open in 2023 is only marginally greater than it was in 2022. Taken together, these figures point to a general tapering of new project investments as the industry concentrates on launching those already in the pipeline.

"We are very happy with CNG. The main roadblock at first was the lack of infrastructure across our longer runs. Many more stations are available today, and we also purchased larger capacity fuel tanks to get us down the road farther between fueling."

– **Daniel Shandy**, Director Equipment & Maintenance, Matheson Trucking

Price and market uncertainty may have contributed to this shift, particularly as the revenues from California's LCFS market continued to decline. Fuel providers who earn LCFS credits and associated revenue for selling CNG and RNG to the California transportation sector are weathering a more than 40% decline in credit prices (Figure 2, Policy and Funding chapter) and do not anticipate a significant turnaround before 2024. Furthermore, California's LCFS administrators are considering a proposal to restrict the amount of RNG that is credit-eligible to fuel volumes delivered through the Western natural gas network, creating

new market risk for RNG developers and investors.[100] This network is not currently defined, however, so a time-intensive process lies ahead before the impact on national production can be fully assessed. Until LCFS administrators make their decisions, credit price volatility and market risk are likely to persist.

A new proposal at the federal level is another reason for producers to monitor developments before further expanding their project pipeline. In late 2022, the EPA proposed new terms for its RFS program that would allow electricity producers to earn monetizable eRIN credits on electricity generated from biomass including RNG and used to power vehicles.[101] If approved in mid-2023 as expected, it could provide an alternative market for RNG, potentially stimulating new production while adding new competition for CNG station operators and fleets. However, a surge in overall RIN generation from this new eRIN pathway could also depress prices if EPA does not appropriately adjust program requirements to compensate for the increased supply, undercutting fuel producers' potential return on investment.

CNG, RNG continue to offer price advantages as use grows nationally

Fossil-based CNG price increased approximately 16% (private retail) and 21% (public retail) from 2021, but the fuel continued to offer a sizeable price advantage compared to diesel.[102] RNG prices were slightly higher but still offered some competition with diesel, especially in states with low carbon fuel programs. Federal data indicates that the national average public retail price of fossil CNG reached $2.73/DGE in 2022, and surveyed fleets report similar prices as well as an average of $3.11/DGE for RNG, with RNG purchased mostly in California.[103] This price advantage, and the protection from the petroleum market's volatility that long-term fuel supply contracts afford, is one reason why 62% of fleets who operate natural gas vehicles (NGVs) expect their use to increase in the next five years, according to this year's survey.

Fossil-based CNG price increased approximately 16% (private retail) and 21% (public retail) from 2021, but **CNG continued to offer a sizeable price advantage compared to diesel**.

Supply shortages due to natural gas pipeline capacity constraints into California prompted a sudden but short-lived price spike in the state late in 2022, with utility SoCal Gas posting retail prices of $6/DGE and leading providers Clean Energy and NOIL advising that consumer prices could double in early 2023 before normalizing by spring.[104,105] Long-term fueling contracts protected many fleets from this volatility, and several fleets cite this model as an important advantage of operating NGVs. Congress added additional security by extending the $0.50/GGE AFTC for three years through 2024.[106] In 2022, industry association Natural Gas Vehicles America (NGVA) advanced legislation for an additional $1/DGE tax credit for RNG, which it hopes to see approved by Congress in 2023.[107]

Fleet demand for NGV continues to rise, indicating high user confidence and satisfaction with this mature clean drivetrain technology. In California, natural gas consumption in transportation rose 9% from 2021 to 2022, as more fleets found RNG to be an easy, cost-effective way to reduce carbon emissions.[108] On average, surveyed fleets who used natural gas (fossil and/or renewable) in the last two years used it for approximately 20% of their vehicle population, the largest penetration rate among users of any of the clean

drivetrains in this study. Nearly half of these users (43%) rely on RNG, often replacing all fossil CNG use with the renewable alternative. In the first half of 2022, Clean Energy reported multiple RNG supply and station agreements for transit, refuse, and logistics fleets, including in states like New York, Pennsylvania, Texas, and Ohio.[109]

Fleet demand for NGVs continues to rise, indicating high user confidence and satisfaction with this mature clean drivetrain technology.

Cummins' 15L coming to market with some OEM backing, expected to meet low emission regulations

Cummins' announcement of a new 15-liter engine for NGVs starting in MY2024 has drawn some early commitments from manufacturers and fleets.[110] PACCAR has already announced plans to offer the X15N with its Kenworth and Peterbilt brands, and Cummins has reportedly received similar commitments and expressions of interest from an undisclosed number of vehicle OEMs.[111] Testing begins in 2023 with Walmart's large private fleet, which will operate the X15N in a handful of its existing trucks at its distribution center in Fontana, California.[112]

The X15N is expected to improve efficiency by 10-15% compared to the current 12-liter engine, nearly closing the efficiency gap with diesel engines.[113] The company intends to certify its engine family to the 0.02g/bhp-hr NOx standard set forth by CARB beginning in MY2024. If achieved, the engine could offer OEMs the ability to earn credits under CARB's Low NOx Omnibus regulation and EPA's proposed new low NOx engine standards in 2024 and 2025. A similar 9-liter option will be released in MY2026 or MY2027.[114] Strong demand for the Cummins X15N — and the upcoming 9-liter version — will likely be concentrated in refuse and HD markets such as mining and cement, where battery technology is less proven as a good fit.

"In 2012, we converted our entire bus fleet to CNG. Today, 521 buses are low-emissions engines and 41 are near-zero engines. 100% of DART's CNG bus fleet now uses RNG."

– **Darryl E. Spencer**, Vice President, Dallas Area Rapid Transit

Industry investments focus on station productivity and expanded RNG sourcing

In 2022, the natural gas fueling industry focused on growing its station presence and utilization in markets with the highest concentration of NGV fleets. Public retail station counts declined slightly (2%) in 2022, down from a 6% closure rate reported in the prior year, with California remaining the state with the greatest station density.[115] Meanwhile, Chevron purchased Beyond6 (formerly American Natural Gas, or ANG) in November, adding 55 CNG stations concentrated in middle and eastern regions of the country to its network.[116,117] Trillium, a CNG provider acquired by the Love's Family of Companies in 2016, plans to open 10 new public fast-fill CNG stations across multiple states in 2023.[118] Public access is important to many NGV operators — 51% of CNG fleets in the annual survey use public stations. These acquisitions and station plans are part of a multi-year consolidation reported in previous years and likely reflect a selective growth strategy indicative of the CNG industry's maturity.

> More RNG production facilities are in California than any other state. Industry investment suggests that producers are **expanding RNG production in regions with extensive agricultural and waste resources**.

The expanded RNG production network similarly illustrates the industry's pursuit of best-fit opportunities. More RNG production facilities are in California than any other state, however a close study of published project records indicates that most of the facilities due to come online in the next year are located elsewhere, including in non-LCFS states.[119] This suggests that producers are expanding RNG production in regions with extensive agricultural and waste resources. One Vermont-based project has the support of Unilever, Starbucks, the Dairy Farmers of America, and BlackRock, which intends to invest $1 billion in more than 100 dairy digesters across the country by 2026.[120,121]

Energy majors are also investing to secure RNG supply for fleets. In 2022, bp and Chevron made investments to increase their supply of renewable options to natural gas fleets. Purchasing Archaea Energy Inc. increased bp's domestic biogas supply by 50% (246,000 DGE per day), adding to an 80-project pipeline that would grow its RNG production five-fold by 2030.[122,123] Chevron identified RNG as an important part of its growth strategy for its CNG fueling station network, partnering with California Bioenergy LLC to develop up to seven dairy digester projects in that state.[124]

Refuse and long-haul continue to lead adoption, though vehicle deliveries drop overall

Available data suggests that the price of NGVs remained relatively constant year-over-year, with increases primarily linked to inflation and supply chain constraints (which was the case for all commercial vehicles, regardless of fuel type). Meanwhile, new NGV registrations declined 4% overall to an estimated 6,212 units, with the largest market segments of transit bus and tractor truck dropping 31% and 35%, respectively.[125] Reduced manufacturer portfolios, long order fulfillment timelines, and supply disruptions collectively contributed to year-over-year vehicle-build volatility. Tractor trucks remained in the top three categories for total vehicles delivered with nearly 2,000 new registrations during the year, landing second after straight trucks (which is primarily refuse trucks), with nearly 2,500 new registrations recorded.[126]

Vehicles commonly used in refuse and delivery applications nearly offset the drop in tractor deliveries. Straight truck (mostly refuse) deliveries increased by 13% after a 30% decline from 2020 to 2021. Refuse is a common application for CNG-powered straight trucks, as the annual survey has consistently found. Meanwhile, orders for Class 6 delivery trucks swelled from nearly zero in 2021 to almost 1,000 in 2022, which may be partly due to ongoing deliveries on UPS's last big NGV rollout plan announced in 2019.[127,128] Deliveries of traditional configurations on CNG transit buses for the year were below that figure. Meanwhile, orders for NGVs commonly used in paratransit, utility, and municipal work continued to decline, with only two new vehicles delivered according to public DMV data.[129] Some local and state regulations are pushing these segments towards ZE technologies based on their typically lower mileage and local route profiles and compatibility with an overnight charging schedule.

> The EPA's Clean School Bus program **allowed CNG school buses to be eligible for federal funds** for the first time.

Replacing diesel with lower-emission options is a public health priority for many school districts, and in 2022, the EPA's Clean School Bus program allowed CNG school buses to be eligible for federal funds for the first time. After nearly five years of steadily declining figures, registration data shows that CNG school bus deliveries grew 35% to more than 90 newly registered units. Deliveries of MD cargo and passenger vans were essentially zero this year, signaling that these applications are not a focus for natural gas powertrains, as many applications in these weight classes are increasingly being met by ZE technologies.

Industry Perspective –Natural Gas Vehicles for America

NGVAMERICA

As 2023 unfolds, fleets continue to face serious challenges in controlling costs and deploying clean technologies as supply chain issues and inflation remain ever present and impactful. Natural gas has not been immune to these forces, but it is in strong position to weather the storm. A plentiful domestic fuel free from conflict forces and human rights challenges, natural gas relies on an already existing nationwide fueling network. At the dispenser, natural gas pricing is relatively stable. Despite cold, damp weather and increased demand, spot market prices have seen contract prices decline significantly through the last quarter of 2022 into 2023. The most recent data from the DOE's AFDC Price Report indicates that toward the end of 2022, retail prices nationally were almost $2 a gallon less than diesel prices.[130]

Vehicles Available for Every Application

Enabled by an expansive list of proven, commercially available MD and HD options, natural gas freight, refuse, delivery, work trucks, and school and transit buses continue to drive natural gas adoption. Cummins offers a full suite of affordable MD and HD natural gas engines in 6.7-, 9-, and 12-liter options. All are certified at a 0.02 g/bhp-hr standard, a level 90% cleaner than the current EPA NOx standard. Coming early next year,

Cummins will add a 15-liter natural gas engine, delivering greater horsepower and torque, further improving efficiency, and providing more opportunities for fleets. Also arriving to market is Texas-based Hyliion's hybrid natural gas Hypertruck ERX, providing a fully electric powertrain powered by RNG or CNG to eliminate the severe range limitations that currently plague the battery-electric truck sector. Additional global manufacturers are considering introducing natural gas products sold elsewhere into the North American market.

The successful launch of these new vehicles could see annual vehicle sales grow by four to five times the current level, with a 50-100% increase in fuel demand in just a few short years. This projected growth could see NGV fuel demand grow to greater than 2.5 billion gallons annually in the next 10 years.

EPA Clean Truck Compliant with Net Zero Carbon Emissions

Natural gas continues to be the most cost-effective and readily available solution for virtually eliminating both criteria pollutants and carbon emissions while meeting demanding daily performance and range needs. NGV America's recent RNG report details how fleets can achieve sustainability goals and save money by transitioning to natural gas vehicles fueled by RNG.[131]

NGV's 0.02 NOx certification means it is EPA Clean Truck compliant today, already achieving the new 0.035 standard set late last year for all MD and HD trucks beginning in MY 2027. When fueled by RNG derived from landfill waste, wastewater, food waste, and agricultural waste, NGVs can achieve a carbon-negative outcome. The average carbon intensity of the bio-CNG mix sold in California in Q2 2022 dropped to -103.67 gCO2e/MJ, the lowest carbon intensity of any transportation fuel or technology.[132]

RNG production and fuel availability continue to grow — 276 production facilities are in operation with 264 more in the planning stages or under construction.[133] Additional states are looking to join California, Oregon, and Washington in adopting clean fuel standard programs. In 2021, 64% of all natural gas used in on-road transportation was RNG, up from 53% in 2020.[134] Since RNG is interchangeable with any NGV in either compressed or liquefied form, RNG is the one low-carbon and carbon-negative fuel that does not require the build-out of infrastructure, since it is dispensed from existing fueling stations.

Incentives for RNG Motor Fuel

Natural gas is the least disruptive, most cost-effective, commercially available clean technology. Fleets can deploy NGVs using public fueling stations with none of

the daytime downtime required by other technologies, count on one-to-one replacement of existing vehicles, and access a variety of tax incentives made available through 2022's IRA. Most significant is the multi-year extension of the $0.50/gallon AFTC for natural gas transportation fuel and the increased fueling infrastructure credit of $100,000 per qualifying piece of alternative fuel refueling equipment. This comes on the heels of 2021's ILJA already benefiting transit agencies, clean school buses, alternative fuel infrastructure projects, cleaner trucks, and low carbon transport strategies.

NGVAmerica's immediate legislative priority is passage of our Renewable Natural Gas Incentive Act to provide a $1.00/gallon tax credit for natural gas motor fuel derived from renewable sources. Introduced in 2022 in both the U.S. Senate and House of Representatives with bipartisan sponsorship, this credit will greatly enhance the outlook for RNG and NGVs once enacted.[135]

All opinions in the above Industry Perspective represent the opinion of the aforementioned organization and do not reflect the opinions of Gladstein, Neandross & Associates (GNA) or the report sponsors.

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Battery-Electric Vehicles

Fleets of all types are planning for, testing, and deploying BEVs

Interest in BEVs has spread across MD and HD fleet sectors, attracting more attention than the other clean drivetrains studied in this report. Among surveyed fleets, 65% that employ clean drivetrains operated battery-electric technologies in the past two years. During this period, BEVs were used by at least half of the respondents in all 11 of the applications tracked in the annual survey, a first for any technology since this report's 2020 inauguration. The industry is testing BEVs across a growing number of applications to understand BEV compatibility and prepare for future adoption.

THE FLEET TYPES LEADING BEV ADOPTION

Fleets leading adoption of MD and HD BEV vehicles and approximate vehicles in operation.

Estimated Medium- and Heavy-Duty Vehicles in Operation

LOW-THOUSANDS — HUNDREDS

While interest in BEVs remains at an all-time high, deployments are concentrated in larger fleets. Every fleet with more than 100,000 vehicles that responded to the survey is now using BEVs, with 78% of 10,000-100,000 vehicle fleets and 84% of 1,000-10,000 vehicle fleets reporting BEV use. When broken up by fleet type, off-road yard truck fleets reported the highest use (85%), followed by logistics-urban/last

mile (73%), and logistics-regional haul/under 250 per miles per day (72%), while school bus fleets reported the lowest rate (50%). Public and private sector does not appear to be an indicator of adoption, with 65% of fleets in both categories reporting BEV use.

Even with high interest among fleets of all types, BEV deployments remain modest and tend to comprise a small fraction of fleets' overall vehicle population.

> **"We're building on 20-plus years of lessons evaluating hybrids, EVs, smart charging, and grid impact in our medium-duty delivery fleet to shape strategies and plans for BEVs in our HD less-than-truckload fleet at FedEx Freight."**
>
> – **Thomas Griffin**, Manager, Strategic Fleet Programs, FedEx Freight

> **90%** of surveyed BEV fleets expect their use to grow in the next five years, the **highest adoption forecast** across clean drivetrains since this study began.

According to survey respondents, BEVs comprise 4% of a fleet's population on average and only six fleets who have used at least one BEV report a 10% or higher penetration rate. Low use rates are to be expected in an emerging market. Most fleets want to pilot BEVs before committing to widespread adoption, both to gain a better understanding of the opportunity and the actual total transition cost, which remains high. In 2022, many fleets also noted supply limitations while manufacturers are still working to ramp up production capacity, and deal with lingering post-pandemic global supply chain challenges.

MD vehicle orders surge, HD orders pull back after early growth spurt, according to public data

While BEV technology is still in its early days and associated sales data is limited, independent research and stakeholder engagement indicate that demand is strong and growing. Nine out of 10 surveyed BEV users expect their use to grow in the next five years, the highest adoption forecast across clean drivetrains in this study. Ceres Alliance, a group of sustainability-minded global companies,

surveyed its members on their ZEV demand in the next five years and found that collectively these companies plan to purchase 24,000 pickups, 42,000 cargo vans, 5,000 step vans, 5,000 box trucks, 2,000 utility trucks, and 6,000 Class 8 tractors.[136] USPS received $3 billion to raise its battery-electric mail delivery truck order from 10,000 to 60,000 by 2028.[137]

> Publicly announced orders of over-the-road Class 2-8 BEVs **rose 640%, from 4,500 in 2021 to more than 33,000** in 2022.

Publicly announced orders of over-the-road Class 2-8 BEVs rose 640%, from 4,500 in 2021 to more than 33,000 in 2022.[138] More than 80% of demand was from orders of BrightDrop's EV600 (7,500 units), and Ford's F-150 Lightning (15,600 units, all models) and eTransit (6,500 units).[139,140] Whereas the EV600 and eTransit purchases are primarily made by fleets, consumer purchases are included in the Ford Lightning sales figures, skewing analysis of fleet-only demand. Despite this, the surge demonstrates the extent to which work truck and delivery fleets are the earliest application likely to scale BEVs — with further proof of this being the large purchases that companies like FedEx, UPS, Walmart, Amazon and others have made with Ford, GM, Rivian, and Arrival as reported in previous years.

Excluding Ford and BrightDrop from the analysis reveals that BEV order volumes held steady from 2021 to 2022. With the exception of school buses, public reports suggest that sales of HD BEVs may have

> **"ZEVs and other alternative powertrains, infrastructure, renewable energy, and funding all continue to make significant strides in meeting and exceeding fleet sustainability targets."**
>
> – **Andrew Cullen**, Senior Vice President - Fuels and Facility Services, Penske Transportation Solutions

declined since 2021. With a significant influx of funding from the EPA's Clean School Bus program, school bus sales surged by almost 300% to over 2,400 in 2022.[141] Refuse manufacturers announced sales totaling nearly 40 units in 2022, demonstrating year-over-year growth in a niche market since the first models became available in 2021. Meanwhile, public records indicate that the original early adopter sector for HD BEVs, transit, saw orders drop approximately 45% to just under 550 Class 7-8 vehicles.[142]

Announced sales of HD tractors dropped by approximately 27% to an estimated 660 units. Data from California's HVIP program, a popular source of funding in the leading early adopter state for Class 8 electric trucks, shows that only six truck vouchers were redeemed in 2022 compared to 29 in 2021, while the number of vouchers awarded and awaiting vehicle delivery nearly tripled from 486 to 1,262 during that period. Meanwhile, some early adopters began reporting significant challenges securing sufficient electricity and charging infrastructure in time to support their expected BEVs.[143] These are among the conditions suggesting that while demand for Class 8 vehicles across many applications is strong, resolving order backlogs, infrastructure delays, and funding program limitations will be the requirements for orders to grow and for deliveries to catch up to demand.

High prices, supply chain disruptions persist and federal funds target onshoring

Diverse economic and production factors complicate the supply landscape for leading and new manufacturers alike. Although demand for BEVs is high, BEV production faces many of the same supply chain challenges as conventional vehicles as well as new constraints, like battery supply. New entrants struggled against the buying power of leading manufacturers to access necessary components, but firms in both categories faced compromises. Rivian slashed its production targets due to component shortages, while Ford closed order books on its F-150 Lightning between December and August for similar reasons.[144,145] Lightning eMotors shifted focus to repowers rather than new builds due to challenges getting base models from Ford and GM.

Supply chain disruptions continued to drive up costs in 2022, preventing the price drops for vehicles and fueling infrastructure that were widely anticipated to accompany industry growth. Material concerns identified in the more mature passenger car market signal that, on average, the sale price of commercial BEVs increased, although exact data by vehicle type is limited. Between May 2020 and May 2022, price hikes in steel, aluminum, cobalt, nickel, and lithium drove up raw materials costs for EVs by 140%, and in 2022, graphite supplies became an emerging concern.[147,148] These have driven battery prices up by at least 14% to between $160/kWh and $270/kWh, even as more models have become available.[149,150]

Historically, the industry has estimated HD truck battery pack prices at approximately twice the passenger car price on a per-kilowatt-hour basis, suggesting that a 450-kWh pack could cost between $144,000 and $243,000 before taxes and fees.[151] This has played a major role in pushing the base price of a Class 8 BEV tractor to between $350,000 to $500,000, or three to five times the price of a new diesel truck — an insurmountable price for most without incentives or financing.[152]

These conditions continue to challenge fleets and manufacturers in 2023, but first deliveries from new high-profile HD manufacturers signify that the market continues to advance. Nikola's battery-electric Tre tractor went into commercial production early in 2022, even delivering beer to the Super Bowl in Los Angeles.[153] After nearly four years of delay, Tesla delivered its first pair of Tesla Semis to demonstration partner Frito-Lay in December 2022, with an additional 13 units due in Q1 2023. PepsiCo expects to begin operating 100 Semis in delivery service with customers including Walmart and Kroger by the end of 2023.[154]

With supply chain challenges stymying deployments, state and federal programs allocated billions to address bottlenecks. The Chips and Science Act and the IIJA together allocate more than $300 billion to develop a U.S. battery industry with a near-term focus on semiconductors, mineral extraction, and recycling.[155,156] Projects announced by mid-December 2022 collectively represent a 250 Gigawatt hour (GWh) increase in domestically produced batteries, enough for more than 500,000 HD trucks.[157] To bolster fleet demand and ensure that manufacturers have ready markets, CARB approved its largest-ever investment in clean cars, trucks, and mobility: $2.2 billion of the budgeted $2.6 billion is being allocated to trucks, buses and off-road equipment, including $33 million for small fleets.[158]

Announced projects to manufacture batteries domestically collectively represent a **250 Gigawatt hour (GWh)** increase in domestically produced batteries, enough for more than **500,000 HD trucks**.

Funding tsunami stimulates demand, especially in school bus and yard truck markets

In 2022, billions of new dollars were directed to transportation electrification in the form of tax incentives, equipment rebates, and grants. While a majority of this funding has come from the federal government, local and state funding has also been sizeable. Public incentive funds are expected to soar to an annual average of $32 billion for the next four to five years, with a heavy emphasis on ZEVs, like BEVs, as detailed in the Policy and Funding chapter.

School bus fleets are ramping up adoption of BEVs in the next several years. Electric school bus orders accounted for nearly 60% of HD BEV sales in 2022, thanks in large part to federal funding targeting this sector.[159] EPA's Clean School Bus program received more than 2,000 applications for nearly $4 billion in funding for approximately 12,000 buses, more than 90% of which were battery electric. In response, EPA nearly doubled its allowable funds to $945 million and issued 398 awards for approximately 2,400 battery electric buses, 100 propane buses, and 16 natural gas buses.[160] An additional 8,500 electric school buses are waitlisted for subsequent funding rounds. These results from the first funding round indicate that school districts may become leading adopters of commercial BEVs, provided they have appropriate financial support.[161]

Demand for battery-electric yard trucks is growing, and record deployments may be on the horizon as manufacturers work through backlog and production bottlenecks. Yard truck orders tripled in 2022, exceeding 600 new units ordered and due for delivery in the next few years.[162] Half of this is attributed to Amazon's order of 329 units from French manufacturer Gaussin, which is breaking ground on its first U.S. production facility in 2023 in response to growing demand and financial incentives.[163]

Orange EV is now emerging as one of the most prolific manufacturers. In 2022, it delivered its 500th electric yard truck for warehouse, yard, and other non-marine operations.[164] It also began developing a model tailored to marine terminals, a growing market segment that began showcasing battery-electric yard truck operations at scale.[165] In 2022, the NorthWest Seaport Alliance opened the nation's first all-electric yard handling facility in Tacoma, Washington, with strong support from multiple funding agencies. At year-end, the Port of Long Beach received a $30.1 million grant to replace a fleet of

While total reported purchases of battery-electric yard trucks grew by more than **225%**, reported deployments only grew **64%**.

diesel yard trucks with 60 battery-electric models. Vehicle testing has been underway for several years and POLB's deployment indicates a readiness to test the technology at scale.

Public data suggests that yard truck manufacturers are struggling to keep up with demand, likely due to supply chain constraints. While total reported purchases grew by more than 225%, reported deployments only grew 64%.[166] California's voucher program, CORE, shows that yard truck deliveries dropped by 50% between 2021 and 2022, where deliveries in 2021 fulfilled orders placed in 2020.[167] Kalmar and Orange EV both announced new investments in production facilities, with Kalmar's new "flex line" designed for high-volume production of its electric yard truck models.[168,169] Taken together, these insights suggest that deliveries will ramp up in the next several years.

Funding is essential to fleet uptake, although dynamics in California's warehouse market may be shifting fleets' approach. Data from California's CORE program, which provides vouchers to reduce the capital cost of off-road equipment and infrastructure, shows that more applicants request funding for vouchers than any other equipment type covered in the program.[170] However, a new regulation on emissions at warehouses presents fleets with an alternative. Effective since May 7, 2021, the WAIRE program allots 177 points for purchasing a ZE yard truck without grant funds. These points are equivalent to a $177,000 value. Given that the WAIRE acquisition credit is effectively a ledger adjustment rather than a monetary award, whether the value of this credit outweighs the potential voucher values from CORE or similar programs depends on the fleet. Although much remains to be seen, it is possible that warehouse fleet customers in California may shift their funding strategy away from CORE, opening that program to more non-warehouse applicants in the coming years.

OEMs expand BEV fleet services, pursue new software solutions

Manufacturers are driving BEV adoption by taking more responsibility for the customer experience beyond the vehicle. GM launched a dedicated energy storage division to develop storage and charging management solutions for customers, attracting early engagement from companies including SunPower and utilities Pacific Gas & Electric and Con Edison.[171,172] Blue Bird rolled out energy services and training support for its electric school bus customers, while Kenworth, Nikola, and Volvo rolled out leasing programs covering charging equipment and installation.[173] Additionally, DTNA has provided comprehensive charging infrastructure assistance to its customers via its eMobility consulting team for the past few years.

Manufacturers are also investing extensive resources in training as first products are delivered to fleet customers. Mack Trucks and Volvo separately certified dozens of dealerships across the country to sell and service their electric products; technicians from dealerships and customer fleets can receive hands-on safety, operation, repair, and sales training at Mack Academy's North American sites.[174] These programs also introduce regular opportunities to iterate on model design, training, and distribution.

Multiple OEMs launched **financing, leasing, charging management**, and even customer **data collection** programs, many by way of online apps.

For many manufacturers, success is now measured by software. Ford asserted that the customer's entire experience during a vehicle's life, including its interaction with charging infrastructure, is critical to widespread electrification. As a result, Ford's CEO said that customer-facing programs and technologies "are the biggest, most exciting land grab of revenue in our history."[175] In 2022, multiple OEMs launched financing, leasing, charging management, and even customer data collection programs, many by way of online apps. Ford and components provider ZF are among the two leading manufacturers who identified software as key to the future of transportation, while Mack's Electrify My Refuse Route offers gift cards towards EV equipment in exchange for data on vehicle-route performance.[176,177]

Commercial fleets build next-generation demonstrations on first foundations

Between June 2021 and June 2022, DTNA and Volvo Trucks concluded landmark demonstrations of Class 8 BEV trucks and charging infrastructure in diverse regional haul conditions.[178,179] The results from these multi-year deployments have informed each manufacturers' production series design, which are currently being delivered to their first customers and will also be deployed in 2023 in the Joint Electric Truck Scaling Initiative (JETSI), a 100-truck fleet trial studying BEV charging and operations at scale with Schneider and NFI.[180] JETSI is expected to inform fleet and funding agencies' approach to electrification, particularly with regards to planning and budgeting for private charging infrastructure — a critical component of BEV adoption that is under significant pressure today.

> **"To rapidly scale Class 8 BEV deployment, it's crucial to work with external partners & be flexible with your timeline. Understand that you may not get it 100% right for the first deployment, but you will take the lessons learned along as you scale this technology."**
>
> – **Carlo Bertani**, Sustainability and Decarbonization, Maersk

Progress has also been made in the niche refuse sector following several years of delays and demonstrations. Fleets continued to buy BYD's 8R in small volumes as new competition booked and filled their own first orders. Reviews from Mack Trucks' first deployment partner for its electric refuse truck, the New York City Department of Sanitation, remain strong for standard refuse collection, and the city has placed follow-on orders.[181] Mack continued to book and fill small-volume orders through 2022, often with fleets in cold-weather climates. Battle Motors sold nearly 50 units to large fleets between September 2021 and November 2022, according to the company, but notes that its product does not currently offer a one-to-one replacement for diesel vehicles in all refuse applications.[182] While several non-traditional manufacturers have tested electric refuse trucks in recent years, the market remains small, although fleets may begin to enjoy more model options in 2023, when Autocar gathers field test results on its E-ACX.[183]

New companies make big investments in trucking or fleet 'as-a-service'

Startups are moving to address barriers to adoption with various "as-a-service" models. These newcomers to fleet electrification offer a "one-stop-shop" model by supplying the vehicle, fuel, service, and registration for an all-inclusive fee. Fleet buyers must provide insurance and must sign a use agreement, often at least five years. Several emerging truck-as-a-service providers received funding and began building out public fleet leasing and charging depots. For example, WattEV will open its first site to regional-haul fleets requiring electric Class 8 tractors, high-power charging facilities, or both under a variety of leasing programs in 2023.[184] It plans to build several more sites as part of an electric corridor connecting Long Beach with Sacramento and will develop a charging plaza at the Port of Long Beach, where fleets are facing mandates to phase in electric vehicles starting in 2023.[185]

Serving the last-mile delivery sector, Zeem Solutions opened the first MD and HD BEV transportation-as-a-service facility near Los Angeles World Airport in March and has more sites in development around the U.S.[186] At full capacity, Zeem's first site will offer 130 Level 2 and DC fast charging stations for leasing and public fleet customers in need of a charge. Zeem leases out approximately 100 MD and HD vehicles from a variety of manufacturers, including SEA Electric, Lightning eMotors, and Volvo, and plans to add another 100 Class 8 tractors from Nikola.[187]

Public investments and megawatt-capable technologies aim to bridge the charging gap

The extreme gap between charging infrastructure availability and charging needs expected this decade spurred new investments in national corridors and public depots. To date, most fleets that have adopted BEVs in any significant numbers have been those that can do so using private "behind-the-fence" charging, with 83% of BEV users in the annual survey relying primarily on private charging infrastructure. Reaching national climate goals or the growing ZEV mandates in many states will require bridging the gap and developing public access charging. This is especially the case with some of these ZEV mandates targeting drayage trucks, which typically do not fuel behind-the-fence, but across regional public infrastructure.

The National Electric Vehicle Infrastructure (NEVI) Program dedicates $5 billion from the IIJA to all 50 states to develop charging infrastructure along common corridors.[188] The first tranche of $615 million awarded in 2022 will establish a charging foundation for passenger vehicles and smaller commercial vehicles. Timely progress depends heavily on the successful collaboration of utilities, charging providers, funding agencies, and early adopters on today's lack of sufficient and consistent power supply, particularly in remote and interstate areas. Meanwhile, stakeholders are lobbying for the NEVI program to recognize commercial charging needs in its second funding round, anticipated in 2024.

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Private companies see an opportunity to tackle public commercial charging. National fueling station company Pilot Flying J committed $1 billion to install Level 2 charging stations at 400 travel centers during the next three years.[189] Both DTNA and Volvo are also working on public charging networks that would be brand-agnostic, with Volvo partnering with Pilot and DTNA partnering with NextEra Energy Resources and Blackrock Renewable Power.[190] Startups TeraWatt and Voltera separately announced plans to build public HD truck charging stations along major goods movement corridors in and through California, with each company having raised $1 billion in 2022 and beginning to invest in their first sites.[191,192]

The advancement of a Megawatt-level Charging Standard (MCS) made 2022 a watershed year for battery-electric transportation. After more than four years of design, testing, and validation, industry association CharIN revealed the MCS at DTNA's Electric Island in Portland, Oregon, showcasing truck charging capabilities up to 3.75 MW. The connector is going through final revisions for adoption as a global standard, and CharIN is working with standards governing organizations SAE International and the International Electrotechnical Commission to draft the specifications into their respective requirements in time for a 2024 release.[193,194] Heavy-duty charging stations with MCS capable infrastructure are expected to be developed shortly after.

Industry association CharIN revealed the Megawatt Charging Standard (MCS) at DTNA's Electric Island in Portland, Oregon, showcasing truck charging capabilities **up to 3.75 MW**.

Tesla published blueprints for its "up to 1 MW" North American Charging Standard (NACS) and sparked fresh debate over charger standardization.[195] Tesla's existing LD vehicle charging network has been recognized as one of the most reliable in the country, but the company is also criticized for using a proprietary NACS plug. The blueprint release could prompt some manufacturers to offer the Tesla plug design for fleets who do not require charging rates over 1 MW, but no MD or HD vehicle manufacturer has yet indicated intent to offer the NACS plug.

Given the challenges created by different charging technologies in the market, it is no surprise that the terms of eligibility for federal funding programs are pushing the industry towards greater standardization. Perhaps as a result, in early 2023, Tesla indicated it would incorporate non-NACS plugs into some of its public stations.[196,197] The first experiences by fleets with the MCS and reliability improvements from other network providers will help determine the extent to which MCS becomes a true national standard.

Uncertainty with power supply prompts investments in cutting-edge technologies

As utilities across the country invoked flex alerts and navigated rolling brown- and blackouts throughout 2022, fleets wondered whether they could count on utilities to charge their BEVs. Nationally, electrical grid capacity must grow 60% by 2030 and 300% by 2050 to meet electrification goals, while also transitioning to zero-carbon power.[198] Power supply became a top concern at year-end in California, as fleet charging and fuel production projects were given multi-year lead times from leading utilities, signaling that ordering BEVs may present infrastructure timing risks to fleets.[199] MD and HD truck electrification is not forecasted to account for a large share of California's load increase through 2050, however, due to utility service limitations today, early adopters in these sectors are already feeling the squeeze.[200,201]

> National electrical grid capacity needs to grow **60% by 2030 and by 300% by 2050** to meet electrification & zero-carbon power goals.

Many early adopters rely on time-sensitive government funds to electrify and often work to reach compliance with government mandates. One study found that multi-year queues for service, uncertainty, and growing costs are delaying grid upgrade and power production projects, even in states with the most ambitious electrification targets, such as California.[202] This presents a significant concern for fleets. According to this year's survey, BEV adopters estimate that only

14% of their electricity use for charging in an average week is produced on site. Without sufficient power supply, the market has already seen growing fleet interest in and use of on-site combustion-powered generators to ensure that appropriate charging infrastructure is in place for when electric trucks are delivered. The Federal Energy Regulatory Commission (FERC) has proposed measures moving through public rulemaking that would remove specific bottlenecks and improve service.[203]

> One study found that **multi-year queues for service, uncertainty, and growing costs are delaying grid upgrades**, even in states with the most ambitious electrification targets, such as California.

Fleets are also exploring innovative solutions for electrical supply reliability. This year's survey of BEV users shows that approximately 9% of electricity use for charging in an average week comes from onsite renewable energy generation and storage, 3% from on-site energy generation and storage from fossil fuels, and 2% from onsite energy storage with offsite energy sources, when averaged across all respondents. Under a grant-funded project, leading fleets NFI and Dependable Highway Express used solar panels as part of their fueling strategy under the Volvo LIGHTS project in California.[204] Maryland's Montgomery County deployed the largest solar-powered microgrid in the nation for a transit fleet, and Electrify America opened the U.S.'s first MW-level solar and storage charging facility in Baker, California, as a model for possible replication in other rural areas.[205,206]

Funding agencies are paying closer attention to the potential for electric vehicles to improve grid reliability. Vehicle-to-grid (V2G) solutions have been deployed in school bus contexts for several years, and in 2022, the California Public Utilities Commission approved three projects for PG&E to evaluate V2G technology in residential and commercial applications through 2024.[207] A separate award from the California Energy Commission (CEC) will test battery-electric and hydrogen fuel cell transit buses as grid assets in Oakland in 2024, marking the first time that hydrogen has provided backup power to a building.[208] Separately, the DOE funded a collaboration between California utilities, state agencies, and governing bodies, labor groups, vehicle charging software developers, and vehicle manufacturers including BYD, GM, Ford, and Lion Electric to validate the commercial viability of various V2G technologies.[209] These are among the projects illustrating the need for multi-faceted solutions to successfully integrate wholly new energy systems with commercial transportation.

Industry Perspective – Edison Electric Institute

Fleet electrification is a growing priority for policymakers and for commercial and public fleet operators, and it represents an important step toward meeting private and public sustainability goals. Today, 40% of the nation's electricity comes from clean, carbon-free sources including nuclear, hydropower, wind, and solar energy.[210] Total carbon emissions from the U.S. electric power sector are as low as they were almost 40 years ago, despite 73% growth in electricity use since then.[212] These reductions will continue: 50 EEI members have announced ambitious emissions reduction commitments, 41 of which aim for net-zero or equivalent by 2050 or sooner. The average lifecycle emissions from EVs are significantly lower than internal combustion vehicles, and that gap will continue to widen as the electric power sector becomes increasingly clean.[213] EVs will play a key role in reducing emissions from the transportation sector as the electric power industry delivers resilient clean energy across our nation's economy.

On the policy front, federal legislation is providing an unprecedented boost to transportation electrification. The IIJA makes more than $20 billion in federal funding available for electric transit buses, electric school buses, public EV charging infrastructure, and clean vehicles and technology over the next several years.[214]

The IRA provides individuals and businesses with tax credits to purchase new, used, and commercial EVs and to install EV charging infrastructure, as well as $7 billion in funding for MD and HD vehicle electrification, port electrification, and electrification of the U.S. Postal Service fleet.[215]

In addition, a growing number of states are enacting or considering the ACT rule that requires manufacturers to sell an increasing share of zero-emission vehicles, making electrification an increasingly attractive path for truck manufacturers and for fleet operators.

Electric companies are well-positioned to support corporate and public fleet customers. EEI member companies are investing more than $4 billion in customer programs to support charging infrastructure and other programs to accelerate electric transportation.[216] A significant portion of this investment is available for charging needs aside from passenger vehicles, including for school buses, transit buses, and other fleet vehicles. These programs typically help to reduce the customer cost of installing charging infrastructure by providing rebates, "make-ready" infrastructure for customers, and/or end-to-end charging solutions. Fleet customers can find more information on these programs in EEI's EV Program Database.[217]

The National Electric Highway Coalition is comprised of more than 60 electric companies that are committed to supporting the deployment of EV fast charging along major travel corridors across their service territories. While initially focused on supporting individual EV drivers, light-duty commercial fleets also stand to benefit from increased availability of public EV fast charging infrastructure. Collaborations, such as the West Coast Clean Transit Corridor Initiative, and private partnerships, such as one between NextEra Energy Resources, DTNA, and BlackRock Renewable Power to deploy public EV charging infrastructure, are laying the groundwork for dedicated medium- and heavy-duty EV charging infrastructure. Studies like National Grid's Electric Highways Study are proactively identifying optimal charging locations for drivers and helping grid operators plan for the electrification of passenger and fleet vehicles.[218]

Electric companies are continuing to support and prepare for the coming wave of fleet electrification. While hurdles such as supply chain constraints for vehicle components and electrical equipment pose a challenge, they also highlight the need for early collaboration between fleet customers and their electric company partners to ensure a seamless transition to the future of electric transportation.

All opinions in the above Industry Perspective represent the opinion of the aforementioned organization and do not reflect the opinions of Gladstein, Neandross & Associates (GNA) or the report sponsors.

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Hydrogen Fuel Cell Electric Vehicles

Big investments and partnerships focus on building supply with a renewable emphasis

Taking a lesson learned from the BEV adoption curve, legislators and regulators are investing heavily in hydrogen production and fueling infrastructure. In doing so, a viable refueling landscape could soon exist as these vehicles become commercially available. In February, the DOE asserted that the country's decarbonization goals depend on a robust domestic supply of electrolytic hydrogen for the commercial transportation sector, due to its relatively low carbon intensity, particularly as the national grid moves towards a carbon-free status. The agency projected a need for electrolyzer capacity to grow by 1,600%, to 3 GW, which will continue to shape its funding decisions. The DOE is currently considering 79 concept papers for its Regional Clean Hydrogen Hub program, which allocates $8 billion to develop six to 10 hubs, or production and distribution centers, to serve industries such as transportation nationwide. Awards are expected in the second half of 2023. [219]

THE FLEET TYPES LEADING FCEV ADOPTION

Fleets leading adoption of MD and HD FCEVs and approximate vehicles in operation.

TRANSIT | REGIONAL HAUL | DRAYAGE

Estimated Medium- and Heavy-Duty Vehicles in Operation

EARLY COMMERCIAL (AROUND A HUNDRED) | DEMONSTRATION (DOZENS)

> The DOE is currently considering 79 concept papers for its Regional Clean Hydrogen Hub program, which **allocates $8 billion** to develop six to 10 **hydrogen production and distribution hubs**.

Private investments by global leaders are also targeting production. Energy majors Shell and Chevron made several investments in hydrogen and renewable hydrogen production worldwide. Recognizing the stark gap between its forthcoming fuel cell electric vehicle (FCEV) products and its target customers' experience with and access to hydrogen, GM is working with Nel ASA to develop renewable hydrogen supplies in target markets.[220] Bosch allocated $1.3 billion through 2025 to develop its hydrogen technology in North America, while Cummins is ramping up electrolyzer production domestically and globally, with products for small and large fuel production facilities.[221]

Analysis suggests that the hydrogen fuel production projects announced in 2022 will add more than 900 metric tons per day of hydrogen capacity by 2023.[222] Most projects plan to leverage renewable feedstocks, and approximately two-thirds of the projected capacity (around 200 million DGE per year) is designed for HD transportation consumers. These projects show promise with involvement from well-capitalized companies, including Cummins, Schneider National Carriers, Chevron, and Air Liquide.

California's hydrogen fueling market offers some hint at a potential future for renewable hydrogen. The state's network of stations that support its goal of one million FCEVs on roads by 2030 has helped establish the market for hydrogen in transportation. The carbon intensity of hydrogen used by vehicles in the state, mostly passenger cars, dropped by 46% to 30 grams carbon-equivalent per megajoule between 2021 and 2022, offering 88% lower GHG emissions compared to petroleum-based fuels.[223] Additionally, the amount of renewable hydrogen consumed exceeded the state's goal of 40% through 2027.[224] If renewable fuel production continues to expand as the supply of hydrogen grows overall, then fleets may be able to count on achieving deep emissions reductions on a well-to-wheel basis.

Vehicle orders slide as new commercial demonstrations are announced

Manufacturers and fleets reported fewer than 100 FCEV orders in 2022, down from an estimated 140 in 2021.[225] This decline is not surprising in a new market with few providers and is largely explained by two manufacturers shifting priorities. After reporting a significant number of advance orders in 2021, startup Hyzon was largely focused on responding to legal concerns and production challenges in 2022 and did not report any new sales. Direct competitor Nikola prioritized its BEV products through mid-2022, although it plans to begin rolling out its FCEV in late 2023. Meanwhile, sales of FCEV buses continued, but public announcements indicate that fleets and manufacturers prioritized filling existing orders in 2022 and incorporating them into transit fleets, rather than placing new orders.

> Manufacturers and fleets reported **fewer than 100 HD FCEV orders in 2022**, down from an estimated 140 in 2021.

As the industry moves through these initial deployments and wrestles with fueling

infrastructure gaps, stakeholders are investing in building buyer confidence. In 2022, a coalition of public transit agencies, manufacturers, and fuel providers formed the Hydrogen Fuel Cell Bus Council to educate policymakers, regulators, and other stakeholders on the benefits and infrastructure needs to grow transit demand.[226]

> **"FCEVs will play a crucial role in Walmart's goal of converting long haul routes to zero emissions. By becoming an early adopter, we can help unlock viable ZE solutions with increased range and lower weight impact, benefiting both our industry and our planet."**
>
> – **Fernando Cortes**, Senior Vice President, Transportation, Walmart U.S.

The first Class 8 tractor demonstrations with FCEVs continued in 2022, with Hyundai preparing for its June 2023 deployment of 30 Xcients in California and startup Hyzon deploying its first units with TTSI in California and Exxon Mobil in Texas.[227,228,229] The FCEV version of Nikola's Tre received an executive order from CARB in late December, allowing the OEM to sell to California customers and apply for state incentives.[230] Nikola plans to make its first customer deliveries in Q3 2023, a major milestone as tractors join transit buses with products that enter early commercially available for purchase and delivery.[231] Other OEMs that have announced fuel cell electric tractors include Hino and Kenworth, with some models available as early as 2024, according to the manufacturers.[232]

Hydrogen fuel cell truck demonstration results have not been released, but these and other announced models are anticipated to meet long-haul range requirements (250-500 miles). Start-up Gemini Motor, Ballard Power Systems, and Chart Industries are developing a Class 8 FCEV with space-saving designs and vehicle software which they expect will allow fleets to achieve a range of 1,000 miles or more, with the first vehicle demonstration expected in late 2023.[233]

Manufacturers and their partners will demonstrate additional hydrogen fuel cell commercial vehicles in both the on- and off-road markets in 2023. DTNA is working with the U.S. Department of Energy to demonstrate a fuel cell electric tractor that exceeds HD long-haul sleeper performance, efficiency, and range requirements, without compromising payload.[234] The Symbio H2 Central Valley Express received $2 million from the CEC to support its project retrofitting a Class 8 tractor with a hydrogen fuel cell powertrain and running it on 400-mile routes between California's Inland Empire and the northern San Joaquin Valley.[235]

The 12-month run is slated to begin in late 2023 and leverage planned hydrogen fueling stations from Air Liquide, Shell, and Trillium. Toyota is active in both the over-the-road and off-road markets. With funding from the government of Japan, Toyota Group's company Tsusho is working with Mitsui and PACECO to demonstrate a Class 8 FCEV for the U.S. drayage market.[236] Kalmar and Ricardo PLC also plan to demonstrate two T2E yard trucks with fuel cell technology at a terminal in the Port of Los Angeles in mid-2023.[237]

The State of Sustainable Fleets survey finds that 10% of fleets who use clean vehicles have operated FCEVs in the last two years, with 63% of them expecting to grow their FCEVs in coming years. Transit and regional/long-haul goods movement fleets have the highest use rates, with approximately 17% of these fleets reporting use of at least one FCEV. These also correspond to the segments that OEMs are targeting.

Transit and regional and long-haul goods movement fleets have the highest use rates, with approximately **17% of these fleets** reporting use of at least one FCEV in the fleet survey.

Fuel prices remain well above competitive range, spike at year-end

Hydrogen prices at the pump held steady from 2021, with average prices dropping only $0.18 from 2021 through the first half of 2022 (to $15.82/kg).[238] Surveyed fleets report paying slightly less in contracts with third parties who deliver hydrogen to their depots, or $12.81/kg compared to $16.00/kg. Erratic weather, natural gas pipeline failures, and declining carbon credit prices in California collided with the economy's inflation, forcing providers to raise consumer prices to as much as $24.99/kg in November 2022. Station operator Iwatani indicated that it may issue a second price hike in early 2023, although as of March, it had not occurred.[239]

With supplies of critical fueling station components still low in a promising but nascent market, station costs did not decline in 2022, and some project data

suggests that they may have increased for high-capacity and fast-fill station designs.[240] Short supply and limited domestic production of electrolyzers, a key component to produce hydrogen from electricity and necessary for many low-carbon hydrogen production plans, contributed to rising station costs.[241] Similar to the increased attention on the battery supply chain, this pain point attracted federal attention, and $750 million was dedicated to developing a domestic electrolysis industry.[242] Producer Cummins also raised its investment in electrolyzer production domestically and globally.[243]

Hydrogen fuel price forecasting is challenging, with close dependency on the costs of feedstocks, production and fueling equipment, carbon credits, land availability, station efficiency, and growth in station populations overall. Regulators add their own uncertainty: New federal funding favors "clean hydrogen," offering a $3 per kilogram fuel production tax credit under the IRA, but further work is underway to define the credit-earning potential of different eligible feedstocks.[244, 245] The final values will have a significant effect on the price of hydrogen, which must fall by at least 50% for the fueling and vehicle technology to be economically viable. While fuel supplies and infrastructure are expected to expand by mid-decade, it will take several years before these have a significant effect on the price at the pump.

> New federal funding offers a **$3 per kilogram** fuel production tax credit under the IRA, but hydrogen prices must **fall by at least 50%** for the technology to be economically viable.

Station counts tick up and fueling is set to expand beyond California

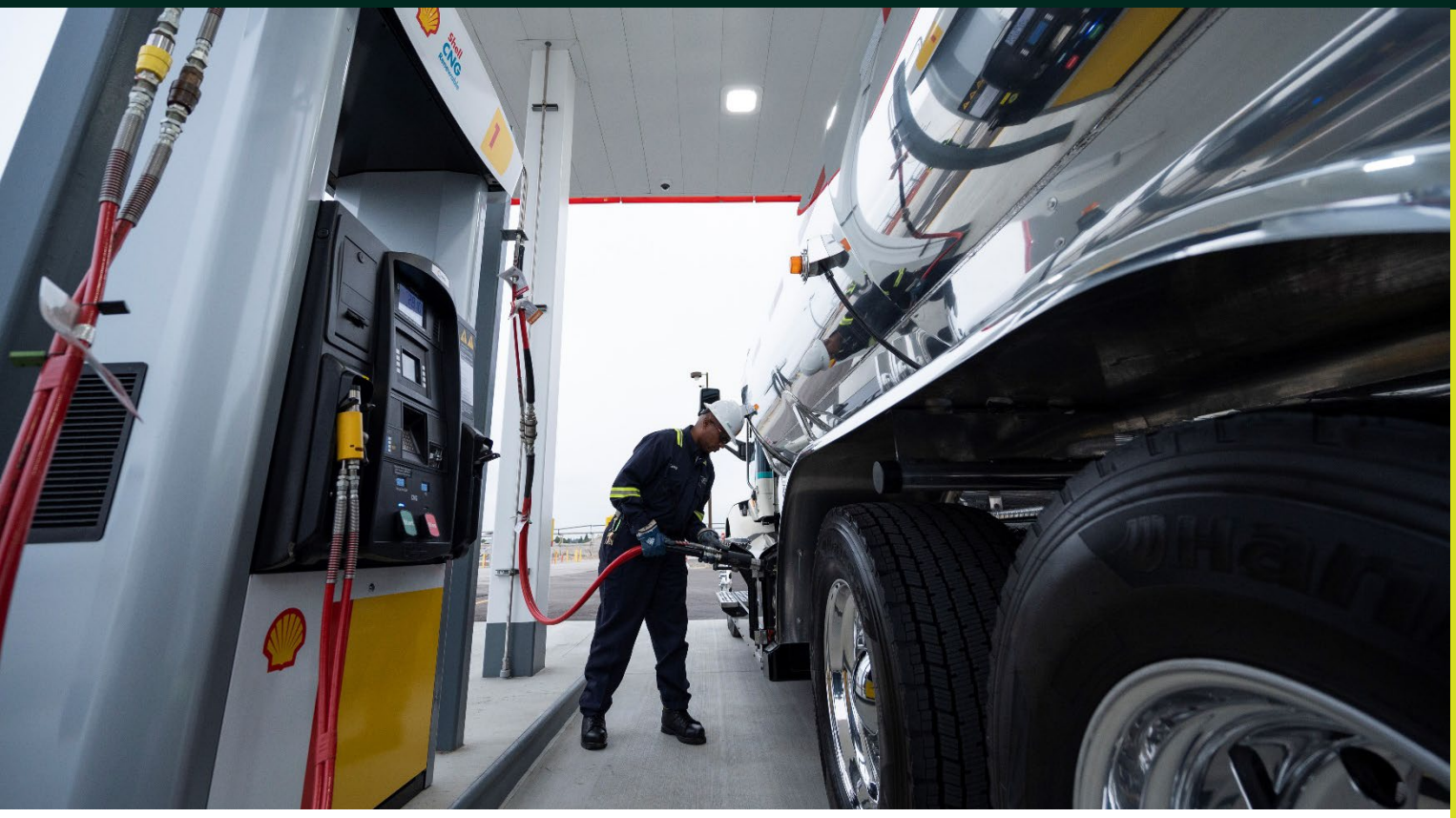
> The national public hydrogen station network **grew by 12%**, mostly in California. Station developers are now beginning to invest in networks across the central, mid-Atlantic, and southwestern U.S.

The number of hydrogen fueling stations in the U.S. has hovered below 50 active stations for several years, as the COVID-19 pandemic introduced construction delays and curtailed demand. According to the Alternative Fuels Data Center (AFDC), the national public hydrogen station network grew by 12% to 54 stations as of January 2, 2023. The vast majority (53) support passenger vehicle use in California, where the industry is working towards a state-established goal of 200 stations by 2025 and designing more to support Class 8 trucks and buses in addition to passenger cars.

While a majority of the focus on FCEV fueling has taken place thus far in California, and in a few select locations around the greater Tri-State area (New Jersey, New York, and Connecticut), station developers are now beginning to invest in networks across the central, mid-Atlantic, and southwestern U.S. Since mid-2021, Nikola has engaged with more than six partners to develop and distribute hydrogen — mostly renewable — for vehicle fueling across Arizona, California, Indiana, Pennsylvania, and elsewhere.[246] In Oklahoma, Woodside Energy is building a facility to produce hydrogen for the HD transportation sector, while Bakken, Cummins, and Schneider requested DOE funding to develop a hydrogen hub for long-haul truck fueling in North Dakota, Minnesota, Wisconsin, and Montana.[247,248]

According to this year's survey, 57% of the fleets that have used FCEVs rely on public fueling, but all users sourced hydrogen from third parties for their FCEV operations, reflecting the lack of public stations designed for commercial fleet use. Between 2024 and 2026, fueling station capacity is expected to triple from 2022, reaching 169,000 kilograms per day.[249] Iwatani, an established provider, plans to open five more California stations in 2023 alone.[250] Going forward, the DOE's $8 billion Hydrogen Hub solicitation is expected to lay a foundation to develop additional hydrogen production, distribution and fueling infrastructure in multiple regions across the U.S.

> Between 2024 and 2026, fueling station capacity is expected to **triple growth** from 2022, reaching **169,000 kilograms** per day.



Vehicle, engine, and component manufacturers pioneer innovative approaches

While the commercial FCEV market continues to mature, some engine manufacturers are expanding the industry's perspective on hydrogen's potential in combustion engines. FCEVs use hydrogen to generate electricity via an electrochemical reaction that powers a vehicle motor, but hydrogen can also be combusted in an engine, similar to natural gas. This approach is less efficient than a fuel cell and can release some pollutants at the tailpipe, but it is generally much cleaner than a diesel engine. The advantages of a combustion hydrogen technology lie in design and cost, as well as the potential to give fleets a runway for adopting fuel cell technology.

Two manufacturers revealed combustion hydrogen technologies at ACT Expo 2022. Westport Fuel Systems' 13-liter H2 HPDI fuel system operates on hydrogen as well as natural gas with equivalent or better power, torque, and efficiency as an equivalent diesel engine.[251] Cummins' 15-liter engine, the X15H, was presented as part of its fuel-agnostic platform.[252] Due in model year 2024, the X15H will be approximately the same physical size as Cummins' 12-liter diesel engine, potentially allowing fleets to swap engines and extend truck body useful lives. Werner Enterprises will demonstrate the engine in 2023 and, if successful, may formalize its initial expressed interest for 500 units.[253]

Manufacturers anticipate that this technology could significantly reduce the cost of transitioning to cleaner fuels in the 2020s and allow more fleets to reduce their emissions sooner than they would while waiting for the ZE fuel cell technology to become available and affordable. Leading technology provider MAHLE is invested in this opportunity. In September 2022, it presented a new power cell unit designed for a hydrogen combustion engine, citing its own forecast that 70% of commercial vehicles will still rely on non-electric solutions by 2035.[254]

> **"Hele-On is purchasing 36 new buses, including many alternative fuels like hydrogen as part of its fleet transformation, setting the path towards 100% zero emissions by 2045."**
>
> – **John Andoh**, Mass Transit Administrator & General Manager, County of Hawai'I Mass Transit Agency

It is reasonable to assume that this technology could garner interest among the fleets that have not yet tested any clean drivetrains that do not face near-term ZEV mandates and would like a cost-effective path to cut emissions. Cummins notes that natural gas infrastructure could be leveraged to support hydrogen distribution, helping NGV fleets adopt hydrogen without absorbing high transition costs.[255] Combustion-based hydrogen may show greatest promise in states without ZEV mandates.

Industry Perspective – California Hydrogen Business Council

CALIFORNIA HYDROGEN BUSINESS COUNCIL

The hydrogen transportation market continues to experience rapid growth in California thanks to recent major federal, state, and private investment. At the federal level, hydrogen fuel and supporting technologies have received major commitments from the Biden Administration and Congress through both the IIJA at the end of 2021 and the IRA in 2022.[256,257] The IIJA created the nationwide $8 billion regional Hydrogen Hubs program to incentivize regional hydrogen economies, including HD transport and goods movement, as well as many other ZEV, fleet, and port incentive programs. The IRA provides extension and expansion of critical tax incentives supporting the production, delivery, and end use of hydrogen and fuel cells. All of these investments are aimed at achieving the

Administration's goal of decreasing the price of hydrogen to $1 per kilogram within the next decade through the Hydrogen Shot initiative.[258]

The 2021-2022 California State budget also allocated approximately $10 billion for HD ZEVs and infrastructure, including fuel cell trucks, buses, off-road equipment, and hydrogen refueling infrastructure.[259] Those funds are technology-neutral and will be divided between battery-electric and FCEV technologies, so hydrogen technology stakeholders will work to ensure an equitable split between the ZE technologies.

In 2022, leading vehicle OEMs deployed their hydrogen-powered Class 8 tractor trucks in demonstrations throughout California. OEMs Nikola, Hyundai, DTNA, Cummins, Hyzon, and a partnership between Toyota and Kenworth demonstrated their technologies — both fuel cell and hydrogen internal combustion — at ports, warehouses, and along HD corridors to develop the technology and showcase how their trucks are readying for commercial deployment.

The fuel cell transit bus (FCTB) market continued to grow. As of December 2022, there were 66 FCTBs in operation in California, with 103 more funded.[260] Transit continues to lead HD FCEV adoption by vehicle count, as California transit agencies that are required to transition to ZEV through the Innovative Clean Transit rule and are planning for FCEVs in much higher numbers than originally predicted.[261] FCEVs continue to climb in numbers on the passenger vehicle side with close to 16,000 fuel cell cars by Toyota, Honda, and Hyundai on the road in California, refueling at 57 hydrogen stations.[262]

Dispensed hydrogen must reach $5-8kg to compete with today's diesel prices, even with the uptick in oil prices. These price levels may be achieved through hydrogen consumption at scale, especially with California's Low Carbon Fuel Standard program incentivizing the use of low/negative carbon hydrogen for transportation. A fleet of 20 fuel cell electric trucks will consume around 1,000kg/day, and a fleet of 100 of these vehicles will consume around 5,000kg/day. The scale of companies looking to produce hydrogen varies from 5,000-30,000kg/day and ranges from sites across California and the rest of the country. Upstart and established hydrogen producers are working tirelessly to deploy new and updated hydrogen production technologies using low carbon renewable feedstocks that will reduce the cost of hydrogen to a positive total cost of ownership for fleet operators.

Private investments, paired with recent government investment, are expected to launch infrastructure along transportation

corridors around the country. Currently, 140-plus stations, primarily for LD vehicles, are planned to be developed in California, Ohio, New York, Rhode Island, Connecticut, and Massachusetts.[263,264,265] However, there are only three HD stations in operation today, with nine additional HD stations funded and in development — only within California — with many more in the planning stage through the aforementioned historic federal and state investments.[266,267] Ensuring vehicle deployment lines up with fueling infrastructure is critical to fleets' success. Although the HD ZE sector looks promising, more funding and quicker deployment of HD hydrogen fueling stations is needed for hydrogen consumption to reach scale and make hydrogen-powered HD vehicles a sustainable option for a greener transportation and goods movement future.

Overall, fleets can expect costs for hydrogen-powered HD vehicles and hydrogen to decline in 12-24 months, especially if these vehicles can be produced at higher volumes, competing with diesel and other clean vehicle technologies. Combined with funding programs that support significant market development, like California's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project that can provide up to $288,000 qualified HD vehicles, hydrogen is an opportunity for fleets to meet their zero-emission and operational performance goals.

All opinions in the above Industry Perspective represent the opinion of the aforementioned organization and do not reflect the opinions of Gladstein, Neandross & Associates (GNA) or the report sponsors.

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[263] US department of Energy. *Alternative Fueling Station Locator*. US DOE, energy.gov/alternative-fueling-station-locator

[264] Hydrogen Fuel Cell Partnership. *Stations Map*. Hydrogen Fuel Cell Partnership, h2fcp.org/stationmap

[265] California Air Resources Board. *2022 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development*. CARB, Sept. 2022, arb.ca.gov/sites/default/files/2022-09/AB-8-Report-2022-Final.pdf. "With the new solicitation, at least 200 stations will be funded by the end of 2025, though the timing to achieve Open-Retail status for all stations will depend on future build schedules." f

[266] Hydrogen Fuel Cell Partnership. *By The Numbers.* Hydrogen Fuel Cell Partnership, 28 Feb. 2023, h2fcp.org/by_the_numbers

[267] Statement refers to the IIJA, IRA, and CA State budgets.

Conclusion

The transition to alternative, clean fuels is accelerating. While this was increasingly clear in prior years, 2022 brought consequential milestones that are paving the way for fleet operators to develop transition strategies. Federal regulators established the performance thresholds and compliance schedules that will shape drivetrain manufacturers' product portfolios this decade. Several leading OEMs signaled that they will begin to transition into the post-diesel era and ramp up investments in ZE technologies. A coalition of states demonstrated their intent to adopt California's ZEV transition requirements, and funding from regulators and the private sector ballooned to historic levels. Even in a challenging economy, fleets show steady interest in mature technologies using CNG, RNG, and propane as well as drop-in renewable fuels, and they are now placing record orders for MD BEVs.

Many milestones remain on the path to a full clean technology transition in the fleet transportation sector. Low-carbon credit markets like those along the West Coast must offer higher credit values and proliferate elsewhere to support clean fuel production and technology adoption. Clean vehicles must prove themselves in an ever-growing set of applications and geographies. Costs for vehicles and associated infrastructure must fall while the rate at which utilities and infrastructure developers can build, deliver, and commission equipment must rise, dramatically in both cases.

This decade will be marked by fleet operators running more clean fuels and vehicles alongside their conventional petroleum-based fleets. Although the rate at which these incumbent fuels shift out of focus will depend on commercial, regulatory, and fleets' own decision factors, diesel and gasoline will eventually become the "alternative" solutions for most fleets. That time in the future will be one of the biggest milestones for the history of this industry – and may be closer than many experts think.

Glossary

AFTC: Alternative Fuel Tax Credit

AV: Autonomous Vehicle

BD: Biodiesel

B5: Fuel blend with up to 5% biodiesel

B20: Fuel blend with between 6% and 20% biodiesel

B100: Pure biodiesel fuel

BEV: Battery-electric vehicle

CARB: California Air Resources Board

Clean drivetrains: LPG/propane, CNG, battery-electric, or fuel-cell electric vehicles

CNG: Compressed natural gas

DGE: Diesel gallon equivalent (a unit of measure)

FCEV: Fuel cell electric vehicle

GGE: Gasoline gallon equivalent (a unit of measure)

GHG: Greenhouse gas; synonym for carbon, carbon-equivalent, or CO2e

HD: Heavy duty

HVIP: Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project

ICE: Internal Combustion Engine

LCFS: Low Carbon Fuel Standard regulation

LPG: Liquefied petroleum gas

MD: Medium duty

NGV: Natural gas vehicle

NZE1: Near zero emissions

OEM: Original equipment manufacturer

RD: Renewable diesel

rDME: renewable dimethyl ether

RFS: Renewable Fuel Standard, a federal program

rLPG: Renewable liquefied petroleum gas, a.k.a. renewable propane

RNG: Renewable natural gas

TCO: Total cost of ownership

ZE: Zero emission

ZEV: Zero emission vehicle

METHODOLOGY

The State of Sustainable Fleets study relies on data published in industry, state, and federal databases; industry reports; proposed and enacted policies; primary interviews with stakeholders; and the responses of 225 fleets to an industry-wide survey. Information is gathered and analyzed by expert clean transportation and energy consultants at GNA. This section describes the scope and methodology for primary data collection; sources of public data are cited throughout the report.

Scope of Study

The survey targeted public and private fleets operating Class 2a-8 vehicles in the U.S. in the following sectors: school, shuttle, state/county/municipal, urban delivery, refuse, utility, transit, regional-haul, long-haul, and off-road cargo handling. Renewable fuels considered in this study include alternatives in the diesel, propane, natural gas, electricity, and hydrogen markets. Hybrid technologies were not studied.

Approach to Data

Throughout this study, a variety of data points were collected from fleets, vehicle technology manufacturers, fuel providers, and industry stakeholders including IHS Markit, the Propane Education and Research Council, and the North American Council for Freight Efficiency. GNA's funding data is generated regularly through its Funding 360 program using information from utilities and federal, state, and local agencies.

GNA's policy outlook is generated from ongoing policy analysis through its Policy 360 program.

Vehicle registration, order, and deployment estimates were based on data from IHS Markit, state and federal grant awards, California large transit agency Zero-Emission Bus Rollout Plans, press releases, and GNA's direct communications with fleets. Average model prices are based on manufacturer-advertised base prices for alternative fuel vehicles in each segment, or where these prices are not available, on advertised diesel or gasoline model base prices are adjusted with industry-defined incremental values appropriate to each alternative fuel technology.

Estimates of the number of vehicles in operation by fleet type are derived from vehicle registration, order, and deployment research conducted by the State of Sustainable Fleets team since 2020 and validated against industry reports and input from leading early adopters.

Transportation Solutions, Daimler Truck North America, Shell, and Dana Inc. — reviewed a draft of the report for technical accuracy. GNA maintained editorial control and decisions over which data, feedback, and examples to publish. Only data that were credible and accurate to the best available knowledge of the assembled experts were included.

The State of Sustainable Fleets 2023 Market Brief represents a comprehensive, technology-neutral analysis of the best data available today for on-road commercial fleets and off-road yard truck fleets. Future reports will update the analysis as new, credible data become available.

Survey Methodology

GNA administered an online survey over a six-week period in October and November 2022 to identify trends and operational performance insights from early adopters of the four clean vehicle technologies (natural gas, propane, electric drivetrain, fuel cell electric drivetrain), technologies for more sustainable use of baseline fleet vehicle technologies (diesel), and use of renewable fuels that can be used to power their relevant vehicle platforms (renewable diesel, biodiesel drop-in blends, renewable natural gas, renewable propane, renewable electricity, renewable hydrogen). Fleets were asked to compare each clean drivetrain technology they had piloted or purchased to their baseline technology of gasoline and/or diesel. The survey did not ask for comparisons between the clean vehicle technologies. 225 fleet responses were received.

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