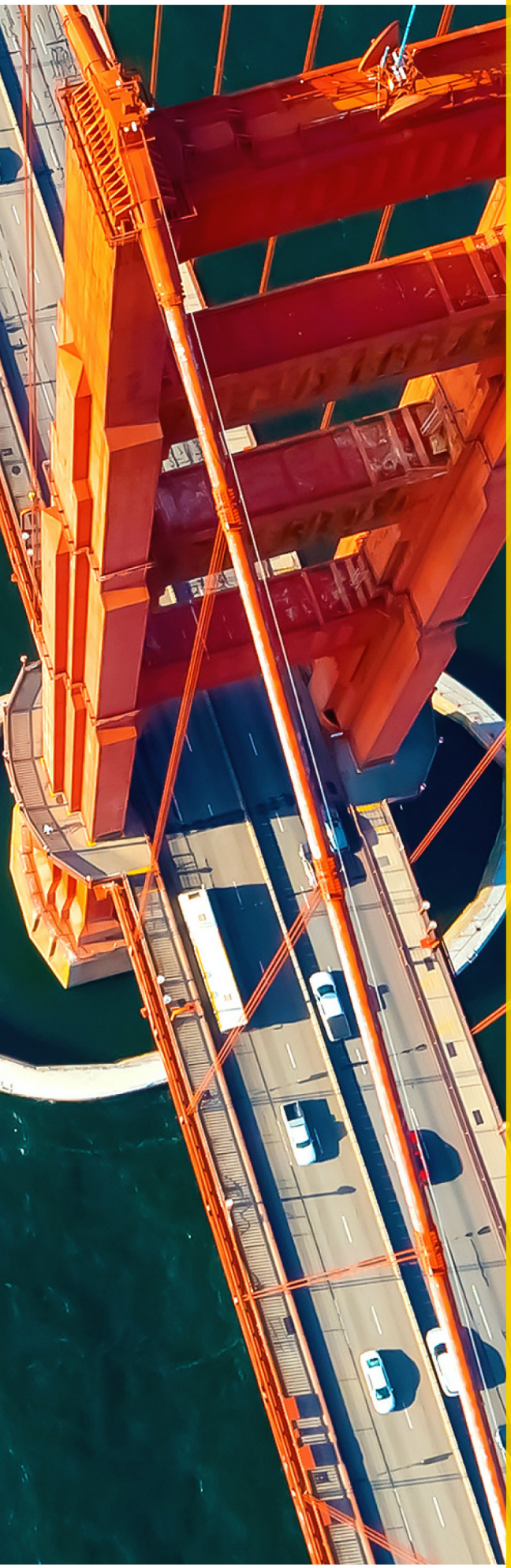

THE STATE OF SUSTAINABLE FLEETS

Market Brief 2022

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Related Material

State of Sustainable Fleets 2020 is the foundational assessment that laid the groundwork for the 2021 and 2022 annual updates. 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 produced a short "Fleet Miniguide" on planning to adopt each of the four leading clean vehicle drivetrain technologies covered in the State of Sustainable Fleets. Each is available at:

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

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ABOUT THE 2022 MARKET BRIEF

The 2022 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.

While the 2020 State of Sustainable Fleets report serves as a foundation, the 2021 and 2022 updates build upon this introductory resource and provides concise insight into the significant trends and developments that occurred over the course of the previous years.

By gathering real-world data directly from early adopter fleets, the State of Sustainable Fleets provides sector-specific insight 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 assessment's comprehensive findings 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 2022 Fleet Survey

At its core, the 2022 Market Brief is informed by a robust fleet survey effort that includes nearly 250 responses from fleet operators and decision-makers who have used clean vehicles and infrastructure. Since the initial State of Sustainable Fleets report published in 2020, the number of survey respondents who provided fleet and operation data more than doubled.

Building upon a rich data source that represents a broad range of real-world fleets in every stage of technology adoption ensures this effort reflects 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. Developments in the sustainable vehicle and fuels market for fleets are occurring so rapidly that an exact assessment is impossible. Each year, the collected fleet survey results are complimented by secondary data and input from the industry's leading experts to improve accuracy as detailed in the Methodology chapter. While this methodology ensures the results are the most comprehensive reflection available of the state of the industry, each fleet owner must evaluate each technology on an individual basis for fit with their specific use cases and locations.

INTRODUCTION

With global vehicle manufacturers setting wide-reaching goals towards zero-emissions (ZE) and fleet leaders around the world following suit, it is increasingly clear that the petroleum-based transportation era has begun its descent, and there is no going back. Tens of billions of dollars are being invested globally by traditional and start-up vehicle manufacturers, infrastructure and low-carbon fuel providers, public and private sector fleet operators of all shapes and sizes, and all levels of governments. A new pathway is being paved for zero- and near-zero emission (NZE) vehicle technologies and low-carbon renewable fuels, with acceleration expected in each subsequent year.

Each year, the State of Sustainable Fleets takes stock of the developments in the U.S. market for leading sustainable technologies and provides guidance to end-user fleets and industry suppliers. It is the largest annual technology-neutral assessment and consolidated source of information on the top sustainable technologies for on-road fleets. Key market trends are documented and analyzed for each fuel and technology type, and commentary is provided on what the market might expect to see in the years ahead.

The 2022 report confirms that the foundation of the sustainable fleet market has now been firmly laid. The rate of growth will be determined by the degree to which each advanced technology and low-carbon fuel can demonstrate economic and environmental sustainability benefits for the end-user. Evidence of this can be seen in the data from this year's report, where traditional alternative fuels and vehicles like natural gas have seen sustained growth and fuel production announcements suggest more growth. Meanwhile, battery-electric and fuel cell vehicles have experienced strong interest and initial uptake but have yet to see market scaling given the lack of consistent economic benefits to complement their environmental ones. While these various fuels and technologies are in different phases of their growth cycle, this year's report validates growth in all for the next decade.

The Perfect Storm for Clean Fleet Market Acceleration

In this year's annual survey of nearly 250 early adopter fleets, one point was clear: End-users have no intention of curbing their planned procurement of sustainable technologies. Nearly 85% of fleets that have used propane, compressed natural gas (CNG), battery-electric vehicles (BEVs), and fuel cell electric vehicles (FCEVs) intend to grow their use of these technologies, a finding that has held steady each of the three years we have surveyed fleets. Many of these fleets have already begun scaling these technologies across their fleets, sometimes reaching nearly 100% conversion

"CNG, renewable diesel, and hybrid electric vehicles have successfully served as interim bridging tools on the path to decarbonization. Next generation BEVs will allow us to build upon our first generation decarbonization strategies, further reduce dependence on fossil fuels, reduce maintenance expense, and increase uptime for our operators."

— Michael Glover, Senior Director Transportation Services, Pacific Gas and Electric Company, California

to CNG or propane, with the largest fleets now seamlessly operating several thousand clean fuel vehicles in their daily operations. Among this cohort of early adopters, the majority are already running multiple sustainable technologies and fuels across their operations. Most are eager to learn the newest sustainable technology, with more than half (53%) having already piloted or purchased BEVs. When asked about future plans, two-thirds (67%) of all fleets we surveyed intend to order BEVs in the next year.

Nearly 85% of surveyed fleets that are early adopters of alternative vehicles intend to grow their use, for a third consecutive year.

This year's fleet survey results were hardly surprising given the growing commitments to increase environmental sustainability, accelerate carbon reduction, and drive environmental, social, and governance (ESG) reporting across the public and private sectors, which was led by many of the world's leading companies. In 2021, PepsiCo, Target, and many others pledged to reach net-zero carbon emissions by 2040, a goal that Amazon, Verizon, Walmart, and others made in prior years. Consequently, there is a growing realization that a fundamental shift away from gasoline- and diesel-based transportation is required to meet these aggressive targets.

In addition to end-user fleet customers, vehicle manufacturers (original equipment manufacturers, or OEMs) have also aggressively stepped up their investments and commitments in clean transportation. The same week that the 2021 State of Sustainable Fleets report was published, Ford announced a multi-billion-dollar pledge to increase BEV development, joining a growing corps of OEMs making similar commitments. Many of the world's largest automakers, including Nissan, Volvo, Stellantis, Volkswagen, and others have affirmed an end in the development of new internal combustion engines in the next five to 10 years. Other vehicle manufacturers, including GM, have gone so far as to announce that they plan to stop selling gasoline and diesel vehicles entirely within the next 10 to 15 years.

Many OEMs, especially those in the medium-duty (MD) and heavy-duty (HD) fleet segments, have already begun taking orders and making deliveries of their BEV products. While no commercial FCEVs made their way to fleet customers in 2021, orders for FCEVs quadrupled across the transit and HD tractor segments, and the first Class 8 FCEV demonstration trucks were delivered to U.S. fleets. Although these deliveries are in exceptionally small numbers, the significance of zero-emission vehicles (ZEVs) being implemented in fleet operations is a milestone achievement.

To keep pace with the scaling of the advanced vehicle technology market, infrastructure and fuel providers have made significant clean fuel investments of their own. Traditional petroleum companies such as Shell and Marathon announced in 2021 that they plan to convert entire refineries to produce low-carbon renewable fuels, which mirrored a similar announcement Phillips 66 made in 2020. In 2021, Chevron presented an array of low-carbon fuel solutions, including renewable diesel (RD), renewable natural gas (RNG), and

"While it has been a challenge in acceptance, the benefits outweigh the risks and our fleet is excited to transition to multiple fuel technologies to reduce our carbon footprint."

— John Christian Andoh, Mass Transit Administrator, County of Hawaii Mass Transit Agency, Hawaii

hydrogen, in addition to BEV charging. Shell has been pursuing a similar strategy for the last several years. To support the growth of the ZE vehicle and truck markets, a growing number of infrastructure and fuel suppliers have steadily increased their investments in EV charging infrastructure, as well as hydrogen fuel production, distribution, and fueling locations. Shell has committed to operating 500,000 chargers globally by 2025 with an ambition for 2.5 million by 2030.[1] Never before has there been so many options and such a robust market for low-carbon fuels to support the growth of NZE and ZE fleets.

Paralleling the rise in private-sector investment, significant new government investments are planned for 2022 and in the years ahead. At the federal level, the $1.2 trillion Infrastructure Investment and Jobs Act (IIJA) has a very strong clean technology emphasis, with numerous multi-billion-dollar programs earmarked to transition specific fleet types to clean vehicles and expand national infrastructure for specific technologies. For example, the U.S. Department of Energy (DOE) will soon release an $8 billion solicitation to support the development of hydrogen hubs around the U.S., which will provide a significant boost to hydrogen production, distribution, and use, including for on- and off-road commercial vehicles. Likewise, the U.S. Departments of Transportation and Energy were allocated $5 billion through the National Electric Vehicle Infrastructure (NEVI) Formula Program to support the development of a national electric vehicle charging network. NEVI will not directly fund the deployment of MD and HD electric vehicles. However, the NEVI funding is designed to fund publicly accessible or multi-fleet recharging stations, so this funding could help broaden the network of available recharging stations for MD and HD fleets. These multi-billion-dollar programs are in addition to $3-5 billion announced in annual incentives from public agencies at the local, state, and federal levels, with California making up a large percentage of this funding. Combined, incentive support for clean transportation technology has increased from an estimated $3 billion historic annual average to a predicted $20 billion in 2022.

"Culver City is one of the first cities in the nation to go to RNG with its vehicles, including transit and refuse. We are now committed to go all-electric with transit by 2028 and move forward as technology progresses."

— Rolando Cruz, Chief Transportation Officer, City of Culver City, California

With a monumental increase in the commitments and investments in clean transportation solutions being made by both buyers and sellers in the commercial fleet sector, and with significant "carrots" also being provided by the government in the form of lucrative funding programs, forward acceleration of these markets is more certain than ever. However, not taking progress for granted, 2021 also saw a meaningful increase in the adoption of clean transportation policies and regulations that will help to further hasten this market transformation.

California's Low Carbon Fuel Standard (LCFS) continued to provide substantial financial benefits to developers and end-users of RNG, RD, and electricity, helping to progress the use of these ultra-low carbon, and sometimes carbon-negative, fuels. Meanwhile, the LCFS program in Oregon also started to gain more traction and Washington's program, once launched, will provide an important forward driver for increased clean fuel use in these markets as well.

[1] Shell Newsroom, "EV Charging Solutions Leader Greenlots to become Shell Recharge Solutions," accessed at https://shellrecharge.com/en-us/solutions/news/ev-charging-solutions-leader-greenlots-to-become-shell-recharge-solutions.

[2] ACT was adopted by CARB in June 2020.

On the regulatory front, five states adopted California's historic Advanced Clean Truck (ACT) rule, and six other states and the District of Columbia initiated efforts to adopt the rule that will require manufacturers of MD and HD commercial vehicles to rapidly increase the sale of ZE trucks and buses during the next two decades.[2] The California Air Resources Board (CARB), the state's clean air agency and author of the ACT rule, is now working to pair the ACT rule with a ZEV fleet purchasing rule, which will likely also be adopted by other states.

While not focused on the alternative fuel vehicle market, California's Low NOx Omnibus (LNO) regulation, adopted in 2021 and now being followed by a similar federal version of the rule, will increase the cost of MD and HD diesel vehicles in 2024 and then again in 2027. State and federal regulations that simultaneously require improved vehicle efficiency and decreased vehicle emissions will raise the cost and complexity of petroleum-based transportation options, ultimately helping to make alternative fuel vehicles more cost competitive and attractive to commercial fleet buyers.

In 2021, an extraordinarily strong foundation for the continued development and future growth of the sustainable fleet market was established. A combination of factors contributed to the significant market momentum, including growing commitments to carbon reductions and net-zero goals, tens of billions of dollars of investments by the public and private sectors, and a strong and growing policy and regulatory framework. There has never been greater alignment between suppliers and buyers of sustainable vehicle technologies and fuels, with the government offering an array of carrots and sticks to ensure that progress is made.

GLOSSARY

AFTC: Alternative Fuel Tax Credit

BD: Biodiesel

B5: Up to 5% biodiesel

B20: 6% to 20% biodiesel

B100: Pure biodiesel

BEV: Battery-electric vehicle

CARB: California Air Resources Board

CNG: Compressed natural gas

Early adopter fleet: Fleets that have used one of four clean vehicle drivetrains (LPG, CNG, BEV, FCEV).

FCEV: Fuel cell electric vehicle

GGE: gasoline-gallon-equivalent

GHG: Greenhouse gas

HD: Heavy-duty

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

LCFS: Low Carbon Fuel Standard regulation

LPG: Liquefied petroleum gas

MD: Medium-duty

NGV: Natural gas vehicle

NZE: Near-zero emission; referring to vehicles with low tailpipe emissions

OEM: Original equipment manufacturer

RD: Renewable diesel

RNG: Renewable natural gas

Scope 1: Direct GHG emissions that occur from sources that are owned or controlled by the company

Scope 2: Electricity indirect GHG emissions from the generation of purchased electricity consumed by the company

Scope 3: All other indirect GHG emissions that are a consequence of the activities of the company, but occur from sources not owned or controlled by the company

TCO: Total cost of ownership

ZE: Zero emission

ZEV: Zero-emission vehicle

FEDERAL, STATE, AND LOCAL POLICY AND FUNDING OUTLOOK

During the last several decades, local, state, and federal policy, regulations, and incentive funding have played a critical role in establishing and building the market for cleaner fuels and vehicle technologies, with natural gas, propane, electric hybrids, and liquid biofuels having greatly benefited from these actions. This trend markedly accelerated in 2021 and into 2022, with substantial growth in both funding and policies to meaningfully promote progress towards a ZE future. BEVs and FCEVs have begun to see the benefits of this increased push, with dramatic growth in these markets expected in the years ahead.

Clean Vehicle Funding Sees Large Boosts

In 2021, an estimated $5 billion in public incentive funding was made available to replace vehicles or expand fleets with clean alternatives, an increase from the average $3 billion that had been made available annually in the last couple of years. This uptick in funding could be accessed through more than 175 state, federal, and local programs, including utility make-ready infrastructure and electric vehicle supply equipment (EVSE) programs.[3]

Funding in 2022 and during the next five years will shatter all prior records, boosted in no small part by the IIJA's $1.2 trillion in federal funding and substantial increases in funding in California. With these new and expanded funding sources, available public incentives for the clean fuel and vehicle market will grow to approximately $20 billion annually across more than 230 programs.

For the next few years, public funding for clean fuels and vehicles will grow to nearly $20 billion across more than 230 programs annually.

Signatories to an MOU to achieve 100% ZE truck sales by 2050 represent roughly half the U.S. economy.

Notable examples include $1 billion for school buses annually for five years, $1 billion for EV charging infrastructure annually for five years, $8 billion for hydrogen hubs over five years, and an increase of more than $1 billion for proposed programs administered by CARB and the California Energy Commission (CEC). In addition, while California's LCFS credit prices were lower in 2021 than they were in 2020, funding from the state's LCFS program will still provide meaningful incremental incentives to operators of clean fuel vehicles. In addition to California, Oregon's LCFS program is now starting to provide important revenue streams for sustainable fleet operators, and Washington's LCFS program will soon follow.

Big Backers Accelerate Policy Supporting ZEVs

In 2020, California passed the first mandate for OEMs to begin selling MD and HD ZEVs. In the past year, Oregon, Washington, New Jersey, New

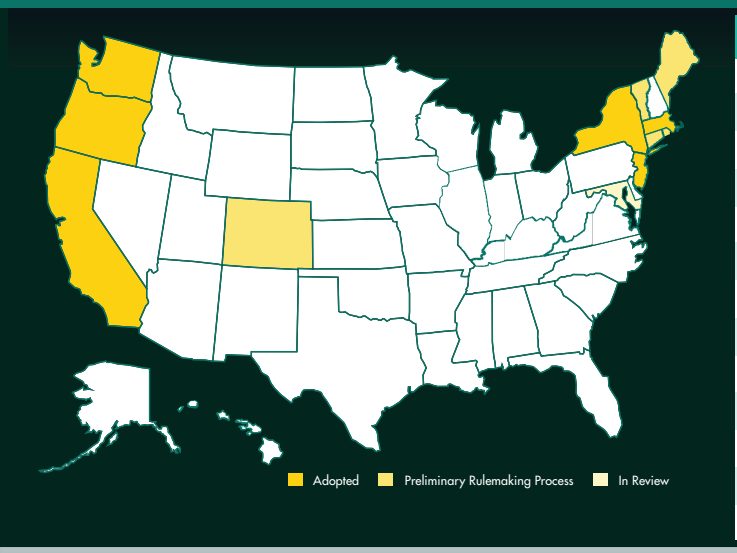
[3] GNA analysis of federal, state, local, and utility programs for on- and off-road R&D, demonstration, and in-use deployment of infrastructure and vehicles. Excludes loan programs. Multi-year programs were annualized.

York, and Massachusetts all adopted California's ACT rule, which will require manufacturers of MD and HD commercial vehicles to rapidly increase the sale of ZE trucks and buses over the next two decades (Figure 1). Six other states and the District of Columbia have also begun preliminary rulemaking or initiated a formal review to consider adoption of the ZE truck sales mandate.

Most of the states that have either adopted or are considering an ACT rule, as well as several more states and Canadian provinces, are signatories to a memorandum of understanding (MOU) to collectively collaborate to achieve a goal of 100% ZE truck sales by 2050.[4] Together, the MOU states represent roughly half of the U.S. economy.

Advanced Clean Trucks Rule Progress

Current Status of ACT Rulemaking Across the U.S.



State	Status	Beginning MY	Fleet Reporting Date
California	Adopted	2024	April 1, 2021
Oregon	Adopted	2025	June 30, 2022
Washington	Adopted	2025	Not required
New Jersey	Adopted	2025	April 1, 2023
New York	Adopted	2025	April 1, 2023
Massachusetts	Adopted	2025	Not required
Connecticut	Preliminary Rulemaking Process	-	-
Rhode Island	Preliminary Rulemaking Process	-	-
Colorado	Preliminary Rulemaking Process	-	-
Maine	Preliminary Rulemaking Process	2026	Not required
Vermont	Preliminary Rulemaking Process	-	-
Maryland	In Review	-	-
DC	In Review	-	-

Current ACT rulemaking status as of April 2022

Figure 1: State of adoption of California's Advanced Clean Trucks Rule

Whereas the ACT regulation requires OEMs to sell ZE trucks, CARB is working on a complimentary regulation that will require fleets to buy these ZE technologies. The draft Advanced Clean Fleet (ACF) Rule — expected to be adopted in late 2022 or early 2023 — 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).

The adoption of the ACF rule to pair with the ACT rule in California — historically representing approximately 8% of annual truck sales — will provide a considerable boost to the market for ZEV fleet technologies and the supporting infrastructure required to fuel them. Of course, should some of the other 10 states and the

The adoption of the ACF rule to pair with the ACT rule in California — historically representing approximately 8% of annual truck sales — will provide a considerable boost to the market for ZEV fleet technologies.

[4] California Air Resources Board, "15 states and the District of Columbia join forces to accelerate bus and truck electrification," 14 June 2020, accessed at https://ww2.arb.ca.gov/news/15-states-and-district-columbia-join-forces-accelerate-bus-and-truck-electrification.

District of Columbia follow with a similar rule pairing, acceleration of this market will increase substantially in the coming two decades.

It is also worth noting the potential alignment between these rules and the goals of the nation's truck manufacturers, which have invested billions of dollars into the development of ZE technologies. The ACF is regarded by regulators and OEMs as the necessary "other side of the coin" to the ACT sales mandate: unless fleets are required to purchase ZEVs, it is unlikely that OEMs will be able to achieve the ACT rule's ZEV sales requirements.

The supply of RD has risen dramatically, causing 84% growth in the volume of RD credits exchanged between Q1 2020 and Q4 2021 on California's LCFS. The oversupply resulted in a steep decline in the price of California LCFS credits falling as low as $112/MT on March 23, 2022. That reflects a nearly 50% drop in value from the market's peak of $218/MT on February 3, 2020.

Critical to the successful implementation of these rules, however, will be the ability for commercial ZEVs to demonstrate an equal or positive total cost of ownership (TCO) for the end-use fleet customer — a milestone that has yet to be sufficiently documented, especially in the MD and HD truck sectors. As California's LCFS incentives have been essential to achieving a TCO goal, the decrease in the credit value in recent months could make this a more challenging objective.

Low Carbon Fuel Standard Prices Drop, Pauses in Advancing to More States

California's LCFS program continues to play an important role in the adoption of clean technology nationally. Reaching $4.7 billion in transactions in 2021, it may be the single biggest contributor to increasing the supply of RNG, and, more recently, it has propelled RD and BEVs to generate the majority of credits in the market. With investments in renewable fuel production having increased in the last two years, the supply of RD has risen dramatically, causing 84% growth in the volume of RD credits exchanged on California's LCFS between Q1 2020 and Q4 2021.[5] The consequence of oversupply resulted

[5] GNA analysis of LCFS credit volumes (MT) by fuel type from Q1 2020 – Q4 2021, accessed at https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries.

in a steep decline in the price of California LCFS credits in the second half of 2021 and the first quarter of 2022, falling as low as $112/MT on March 23, 2022. That reflects a nearly 50% drop in value from the market's peak of $218/MT on February 3, 2020.

At the time of the 2021 State of Sustainable Fleets report, it also appeared that low-carbon fuel programs would be proliferating around the country. Washington State had just adopted their Clean Fuel Program, and similar bills had been introduced in Minnesota, New Mexico, and New York. Although there remains a continuous push in these states for their version of a low-carbon fuel program, this momentum appears to have slowed. This past February, legislation introduced in New Mexico failed to pass by one vote, and measures in other states have been held up. Post-pandemic inflation exacerbated by soaring gasoline and diesel prices has made most state legislatures wary of any new laws that would appear to increase costs to consumers.

A New Local Emissions Standard Gets State-Level Attention

Battling some of the worst air quality in the nation, the South Coast Air Quality Management District (South Coast AQMD) in Southern California passed a new regulation in June 2021, the Warehouse Indirect Source Rule (WAIRE), that will provide an important impetus for the forward growth of the clean fuel fleet vehicle market. The rule requires operators of warehouses with 100,000 square feet or more (of which there are approximately 3,000 in the South Coast AQMD's jurisdiction) to mitigate the air quality impact of the diesel trucks coming to and from their facility. Designed as a points system, warehouses generate point deficits based upon the number of diesel truck trips. These deficits must then be offset with points earned from a menu of emission-reducing or technology-enabling actions, such as installing low-emission energy and vehicle technology on-site and/or requiring visits of ZE and NZE trucks to

The Warehouse Indirect Source Rule (WAIRE) requires operators of approximately 3,000 warehouses in Southern California to mitigate the air quality impact of the diesel trucks coming to and from their facilities. It covers one of the busiest cargo hubs in the country.

the property. Alternatively, companies can pay a mitigation fee for each deficit short of the annual requirement, and the South Coast AQMD will use the funds to provide incentives for cleaner transportation technology.

WAIRE covers one of the busiest cargo hubs in the country, and the South Coast AQMD is now evaluating whether to establish similar requirements for the Ports of Long Beach and Los Angeles. These rulemakings have attracted national attention, as bills were recently introduced in the New Jersey and New York legislatures to implement a similar emission-reduction program targeting logistics on a statewide basis. These bills represent an ongoing trend in which innovative emission-reduction policies that originate in California, in this case seeking to address indirect sources of air pollutants and GHG emissions, are considered and replicated in other states.

Reduced Support for CNG and Propane

Today, natural gas and propane vehicles provide a cost-effective means for fleets to replace diesel trucks and achieve significant NOx and particulate matter (PM) emission reductions from MD and HD vehicles. CNG and propane were the original favorites of policymakers and the agencies that administer incentives, and while some of that support continues, there is also a growing preference among policymakers to limit funding to ZEVs as detailed above.

As of January 1, 2021, fossil-derived propane used in transportation transitioned from a credit-generating fuel to a deficit generating fuel in the California LCFS program, imposing a cost penalty on traditional propane in the state. Renewable propane remains a credit generator in the LCFS program.

The federal Alternative Fuel Tax Credit (AFTC) provides a 50 cent per gasoline-gallon equivalent (GGE) tax credit for CNG and 36-cent rebate for propane fuel, plus an additional benefit of a 30% or up to $30,000 investment tax credit for infrastructure.[6] However, the AFTC expired at the end of December 2021, marking the ninth year of the last 12 that it was only renewed on a single-year basis. Furthermore, California removed

[6] Sanchez, Erick, "NGVAmerica Releases Updated AFTC Filing Fact Sheet," 6 January 2021, accessed at https://ngvamerica.org/2021/01/06/ngvamerica-releases-updatedaftc-filing-fact-sheet/.

funding for NZEs that benefitted CNG and propane in several popular incentive programs for fleets, including the Hybrid and Zero-Emission Incentive Program (HVIP). Propane vehicles and NGVs were most affected by these changes. Additionally, as of January 1, 2021, fossil-derived propane used in transportation transitioned from a credit-generating fuel to a deficit-generating fuel in the California LCFS program, imposing a cost penalty on traditional propane in the state. Renewable propane remains a credit generator in the LCFS program.

In an exception to the trend-favoring ZEVs, a new rule expanded support for use of NGVs to maximize their useful life at the state level. Texas passed HB963 in June 2021, expanding the Texas Natural Gas Vehicle Grant Program to include new or used NGVs. The bill increases the residual value for the seller of an NGV, who are often large fleets that sell these vehicles before the end of their useful lives. This has the effect of providing a lower-cost NGV for a buyer willing to retire an older diesel vehicle.[7]

While incentive funding for natural gas and propane-powered vehicles is declining, gaseous fuel technology options have now generally progressed to a commercialization status where incentive funding is no longer required for adoption and the demonstration of a positive TCO. This is a significant milestone for the commercial alternative fuel vehicle sector. Fueling infrastructure is inexpensive or available at no cost to an end-user (via a term agreement with a fuel supplier), fueling is fast and easy, and fuel cost savings — especially in fuel-intensive MD and HD applications — can provide a very attractive return on investment (ROI) to end-users. As diesel-powered vehicles increase in cost and maintenance complexity in the coming years, the business case for gaseous-fueled vehicles will further improve and adoption is expected to increase even without significant incentives.

While incentive funding for NGVs and propane vehicles is declining, incentive funding is generally no longer required for adoption with a positive TCO.

[7] Texas Natural Gas Vehicle Alliance, "Texas Gov. signs first bill that offers incentives for pre-owned NGVs," 15 June 2021, accessed at http://www.ngvjournal.com/s1-news/c1-markets/texas-governor-signs-first-us-bill-that-will-promote-adoption-of-pre-owned-ngvs/.

FLEET SUSTAINABILITY: NEAR-ZERO-, ZERO-EMISSION, AND RENEWABLES REQUIRED

Sustainability has gained increasing momentum in the transportation industry over the last several years and there is mounting pressure for fleets to not only dramatically reduce emissions, but to adopt holistic and proactive management strategies that encompass all areas of fleet sustainability. There is an established set of sustainability practices, tools, and reporting frameworks that help fleets navigate sustainability while adhering to accepted global standards. The two most ambitious GHG emission standards in sustainability — net-zero targets and science-based targets – both generally translate to GHG emissions reductions of 80-100% by the year 2050 which requires some combination of clean and efficient vehicles, ultra-low carbon renewable fuels, and zero-emission technologies.

The trend in supply chain sustainability is zeroing in on transportation-related GHG emissions.

For-hire fleets will need to set a net-zero or science-based target for GHG emission reductions to meet growing expectations and pressure from shippers.

Efficiency is a critical foundation of sustainability, but low-carbon renewable fuels and clean fuel vehicles are essential to reaching aggressive GHG-reduction targets.

Sustainability Targets GHG Emissions from Transportation

Sustainability — a holistic, goal-driven approach to achieving environmental, social, and business impact — has gained significant momentum within the transportation supply chain in the last several years. According to one analysis, 92% of S&P companies and 70% of Russell 1000 companies publish sustainability reports.[8] Furthermore, 80% disclose carbon emissions, including 13,000 companies worth more than 64% of global market capitalization.[9]

A robust set of practices and frameworks honed over decades by a faction of companies, scientists, and non-governmental agencies guide organizations to navigate sustainability for themselves, while providing a range of reporting frameworks in which to align their efforts. Established sustainability practices include identifying core areas of focus, setting targets, building strategies and management plans to meet goals, and publicly reporting on progress through popular standards such as the Global Reporting Initiative (GRI), the Carbon Disclosure Project (CDP), or the Global Emissions Logistics Council (GLEC) Framework.[10,11,12] Fleets already manage numerous social and environmental risks through worker and driver safety programs, community investment projects, and air quality emissions compliance initiatives which can be used, in part, to comply with globally recognized sustainability standards.

> **"We have had great success using alternative fuels going back over a decade. Our fleet size has grown over 40% in that time, but our carbon emissions are lower than 2007 levels."**
>
> — Will O'Connor, Fleet Program Manager, City of Austin, Texas

The practice of sustainability is focused on addressing the largest unmitigated social and environmental factors, and for the transportation industry, there is no gap larger than the GHG emissions that contribute to climate change. Transportation is the top source of U.S. greenhouse gas (GHG) emissions — ahead of both the electricity and industrial sectors.[13] Within that, MD and HD vehicles account for a quarter of the nation's total GHG emissions, more than aviation and not far behind passenger vehicles.

Sustainability standards such as the Sustainability Accounting Standards Board's (SASB) guidance for on-road transportation place fuel and GHG emissions in its top five risks factors to be managed by fleet sustainability programs.[14] In response to growing consumer demand and mounting regulatory pressure, leading companies such as Walmart, HP, AB InBev, IKEA, Nike, and others are looking to their carriers to reduce supply chain GHG emissions, with more shippers expected to join them in the near term.[15]

Fleets Need to Evaluate Net-Zero and Science-Based Targets

As with all aspects of sustainability, GHG goals are governed by established standards. The two GHG emission standards that are most credible are net-zero targets (NZT) and science-based

[8] Governance and Accountability Institute, "92% of S&P 500® Companies and 70% of Russell 1000® Companies Published Sustainability Reports in 2020, G&A Institute Research Shows," 16 November 2021, accessed at https://www.globenewswire.com/news-release/2021/11/16/2335435/0/en/92-of-S-P-500-Companies-and-70-of-Russell-1000-Companies-Published-Sustainability-Reports-in-2020-G-A-Institute-Research-Shows.html.

[9] CDP, "CDP reports record number of disclosures and unveils new strategy to help further tackle climate and ecological emergency," 14 October 2021, accessed at https://www.cdp.net/en/articles/media/cdp-reports-record-number-of-disclosures-and-unveils-new-strategy-to-help-further-tackle-climate-and-ecological-emergency.

[10] Global Reporting Initiative, downloaded 7 February 2022, accessed at https://www.globalreporting.org/.

[11] CDP, downloaded 7 February 2022, accessed at https://www.cdp.net/en.

[12] Smart Freight Centre, downloaded 7 February 2022, accessed at https://www.smartfreightcentre.org/en/how-to-implement-items/what-is-glec-framework/58/.

[13] "Inventory of U.S. Greenhouse Gas Emissions and Sinks - Overview of Greenhouse Gases and Sources of Emissions," U.S. Environmental Protection Agency, 14 April 2022, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

[14] Collins, Andrew, et al., "ROAD TRANSPORTATION Research Brief," Sustainability Accounting Standards Board, September 2014, accessed at https://www.sasb.org/wp-content/uploads/2019/08/TR0402_Road_Industry_Brief.pdf.

[15] GNA analysis of shipper sustainability goals that include transportation-specific goals and expectations for carriers.

A science-based or net-zero target generally requires

80-100% fleet GHG emission reductions

by 2050.

targets (SBT). Both generally translate to GHG emissions reductions of 80-100% by the year 2050.[16] Emission standards focus specifically on GHG emissions because these are the set of emissions that contribute to the warming of the planet and have the most direct impact on human life and the environment, after criteria pollutants, which are regulated by the federal government.

The term "net zero" is defined in the global climate treaty referred to as the Paris Agreement, which was adopted by nearly all of the world's governments in 2015. Net zero refers to a state in which emissions of GHGs are equal to the global capacity to remove those emissions.[17,18] In practical terms, for most fleets, reaching net zero means eliminating all GHG emissions resulting from their operations (Scope 1 and 2 emissions) by a time-bound goal.

An SBT refers to setting a target that is aligned with emissions reductions needed to meet the goals of the Paris Agreement to avoid warming the planet to life-threatening conditions. The Science Based Targets Initiative (SBTI) is a partnership of four non-governmental organizations that established standards and verifies that the targets that companies and governments set align with the Paris Agreement.[19] In the case of fleets, an NZT is considered "science-based," and the SBT certification brings with it the added credibility of third-party verification. However, an SBT can be short of a NZT so long as it is scientifically credible as validated by the SBTI.

Numerous companies in the transportation supply chain have set either an SBT or a NZT, including Amazon, Walmart, Coca-Cola, Home Depot, Nestle, PepsiCo, Target, Sysco, Unilever, Waste Management (WM), Ford, GM, Toyota Motor, Volvo, BMW AG, Daimler AG, Isuzu Motors, Hyundai Motor Co., Cummins, Shell, and many others.[20] However, according to the annual State of Sustainable Fleets survey of the earliest fleets

Numerous companies in the transportation supply chain have set either an SBT or a NZT, including Amazon, Walmart, PepsiCo, Target, Sysco, Waste Management (WM), Ford, GM, Toyota Motor, Volvo, Daimler AG, Hyundai Motor Co., Cummins, Shell, and many others.

to adopt alternative fuel technologies, fewer than half (45%) have an emission-reduction target and only 5% say those targets are either net zero or science-based. Among the top 25 for-hire carriers in the U.S., only UPS, CN, and FedEx have a GHG target that is considered equivalent to a NZT or a SBT.[21]

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[16] GNA analysis of transportation company targets on the Science-Based Targets Initiative and MD and HD road transportation emissions reductions in the IEA Sustainable Development Scenario and Net Zero by 2050 Scenario.

[17] United Nations Framework Convention on Climate Change, "The Paris Agreement," downloaded 7 February 2022, accessed at https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

[18] Net Zero Climate, "What is Net Zero?," downloaded 7 February 2022, accessed at https://netzeroclimate.org/what-is-net-zero/.

[19] Science Based Targets, downloaded 7 February 2022, accessed at https://sciencebasedtargets.org/.

[20] Net Zero Tracker, downloaded 7 February 2022, accessed at https://zerotracker.net/.

[21] GNA analysis of FleetOwner Top 500 For-Hire Carriers 2021, accessed at https://www.fleetowner.com/research/fleetowner-500/document/21154698/2021-fleetowner-500-top-forhire-fleets.

Efficiency is a Starting Point, but Cannot Get There Alone

Most fleets begin working toward GHG emission reductions via increased efficiency, which leads to cost and fuel savings, a reduction in times for routes and deliveries, and an overall decrease in capital-intensive assets. Of course, efficiency improvements also afford GHG emission reductions, providing greater alignment between benefits for both the fleet and its customers' sustainability goals. In contrast to their record on setting NZTs or SBTs, all the top 25 for-hire carriers have reported efficiency gains in the past decade.[22] Participation in the U.S. EPA SmartWay Program has been the most common way that both shippers and carriers align on efficiency goals.

Efficiency is also essential to right-sizing the fleet to adopt renewable fuels, NZEs, and/or ZEVs. For example, in 2006, after being one of the first companies to commit to operating entirely on renewable energy, Walmart first planned to cut $1 billion in fuel use and double its fleet efficiency. [22,23] This first step in fleet sustainability establishes an important foundation and reduces the overall need that other sustainable technologies would then have to fill.

While efficiency measures provide important benefits, they alone are not nearly enough to reach an NZT or an SBT without being paired with other more aggressive GHG emission reduction approaches. In its analysis of scenarios for the transportation sector to reach NZTs or SBTs by 2050, the International Energy Agency (IEA) found that efficiency could only get MD and HD road transportation just over one-third (34%) to the goal.[25] Some limits to efficiency are already apparent. While today's diesel engines operate at an incredibly high rate of thermal efficiency and gains of roughly 20% are theoretically possible, further gains will eventually be limited by thermodynamics, as well as the complexity of near-term criteria pollutant emission control regulations.[26]

While efficiency measures provide important benefits, they alone are not nearly enough to reach an NZT or an SBT without being paired with other more aggressive GHG emission reduction approaches.

SBTs and NZTs can require that fleets achieve the halfway point of their goal by 2030 or 2035.[27] In its analysis of HD on-road transportation, IEA finds that renewable fuels, hydrogen, and electricity are all critical to reaching this level of GHG emissions reduction.[28] Biofuels play an initial role in achieving emission reduction gains for MD and HD transportation throughout the 2020s when ZEVs then become increasingly critical the following decade until nearly 100% of truck sales in 2050 are ZEVs.

While the IEA evaluates the on-road transportation sector as a whole, every fleet must create its own

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[22] Ibid

[23] Walmart, "Wal-Mart is taking the lead on Environmental Sustainability," 2 March 2006, accessed at https://corporate.walmart.com/newsroom/2006/03/02/wal-mart-is-taking-the-lead-on-environmental-sustainability.

[24] Tinker, Josh, "These Two Drivers Helped Jumpstart Walmart's Fleet Efficiency," Walmart, 16 December 2015, accessed at https://corporate.walmart.com/newsroom/sustainability/20151216/these-two-drivers-helped-jumpstart-walmarts-fleet-efficiency.

[25] GNA analysis of IEA Sustainable Development Scenario, accessed at https://iea.blob.core.windows.net/assets/7f8aed40-89af-4348-be19-c8a67df0b9ea/Energy_Technology_Perspectives_2020_PDF.pdf.

[26] GNA analysis of U.S. DOE SuperTruck Program, U.S. EPA Phase 2 GHG regulation, and announcements by engine manufacturers.

[27] Sporrer, Alyssa, "How is the Science Based Targets initiative impacting the freight industry?," FreightWaves, Inc., 15 September 2021, accessed at https://www.freightwaves.com/news/how-is-the-science-based-targets-initiative-impacting-the-freight-industry.

[28] International Energy Agency, "Energy Technology Perspectives 2020," downloaded 7 February 2022, accessed at https://iea.blob.core.windows.net/assets/7f8aed40-89af-4348-be19-c8a67df0b9ea/Energy_Technology_Perspectives_2020_PDF.pdf.

approach to sustainability. Fortunately, a growing number of renewable fuels, NZEs, and ZEVs offer the dramatic emissions reductions needed to achieve net-zero operations and SBTs. California's LCFS program, which reached $4.7 billion in transactions last year, is the largest market to quantify emissions benefits of these fuels and it provides the clearest picture of currently available low-carbon technologies and their emission reduction potential. Credits are generated by the use of low carbon fuels in transportation to reduce GHG emissions, with each credit representing one ton of emissions reduction relative to gasoline or diesel fuel. Emissions reductions are calculated based on the GHG emissions of each fuel over its entire lifecycle (feedstock production, fuel production, distribution, and end use) as compared to the average lifecycle emissions for diesel and gasoline used in California. U.S. EPA emission data can also be used to validate the emissions reduction potential of each technology. The volume of credits for each fuel/technology pathway generated in the LCFS program annually provides a snapshot of the use of these fuels by fleets in California today.

> **"Our diverse fueling enabled us to reduce our carbon footprint by 23% in the last three years. We will continue to reduce our carbon emissions through all these technologies."**
>
> — Kelly Reagan, Fleet Administrator, City of Columbus, Ohio

Combined with efficiency, each fleet can choose a portfolio of these technologies to achieve a NZT or SBT (Figure 2). The LCFS and EPA data show relative Scope 1 (direct) and Scope 2 (purchased electricity) emission reductions for each technology compared to diesel, as fleets would account for and report them in adherence to the GHG Protocol's Corporate Standard.[29] Experiences by early adopter fleets, and the state of the market for these various fuel and technology choices, are covered in detail in the rest of the State of Sustainable Fleets report.

[29] World Resources Institute and World Business Council for Sustainable Development, "GHG Protocol: A Corporate Accounting and Reporting Standard, Revised Edition," March 2004, downloaded April 11, 2022, accessed at https://ghgprotocol.org/corporate-standard.

SCOPE 1 AND 2 GHG EMISSIONS REDUCTION COMPARED TO DIESEL

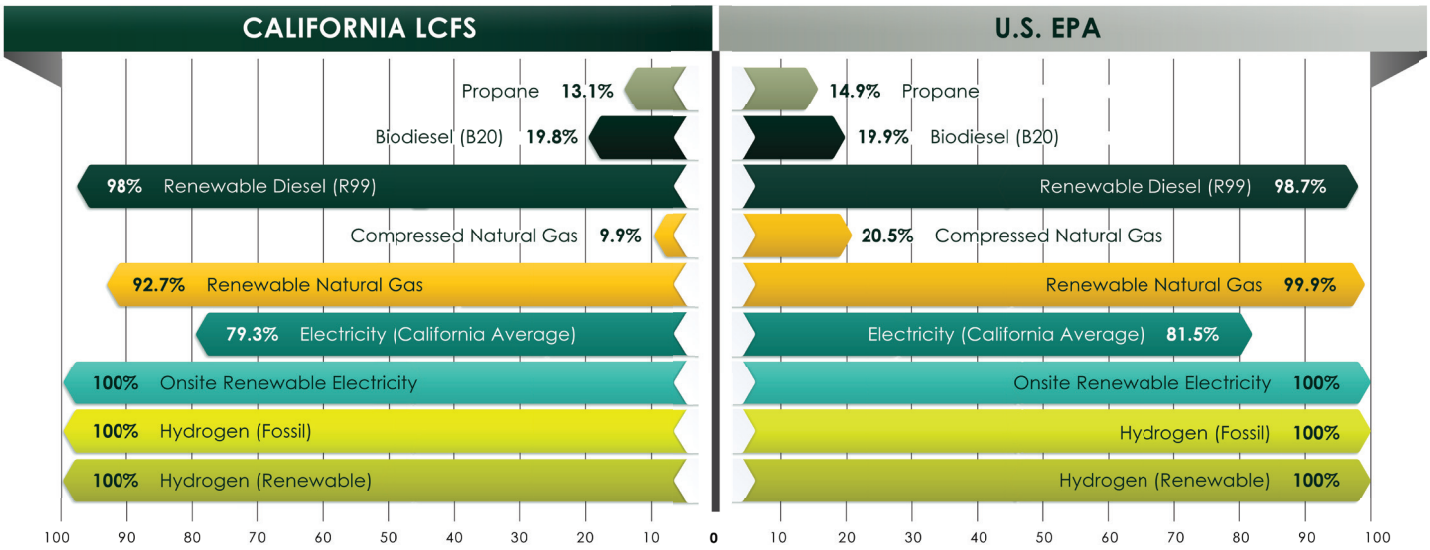

Figure 2: Scope 1 and 2 GHG Emissions Reduction Potential of Leading Renewable, Near-Zero, and Zero-Emission Technologies for Fleets as Compared to Diesel

Sustainability leaders with their own fleets are already showing the way. Many large corporate fleet owners, such as UPS, PepsiCo, and WM, have had sustainability programs for more than a decade, all with ambitious GHG goals. They prioritize efficiency and utilize a portfolio of other solutions, including RD (UPS, PepsiCo) and NGVs operating on RNG (UPS, PepsiCo, WM). Additionally, they are all piloting or purchasing ZEVs and consider that technology critical to meeting their long-term goals.

For fleets that are new to sustainability, a good place to start when trying to determine how to best reduce GHG emissions is to first calculate the total annual GHG emissions from the operation, thereby establishing a baseline. From here, GHG emission reductions achieved from efficiency programs, and the use of renewable fuels and clean fuel vehicles can be evaluated to determine the potential gains that can be realized from each option, and when combined. Making the leap to evaluating the viability of an SBT or NZT typically involves a comprehensive review of the fleet, often facility-by-facility, to compare to emerging NZE, ZE, and renewable fuel alternatives and forecasting their development and costs to set an NZT or SBT.

While taking such a step is new and daunting to most fleets, it has already been performed in other difficult-to-decarbonize sectors such as aviation and manufacturing and doing so may be an expectation to meet customer, societal, and global sustainability aims.

[30] GNA analysis of 2021 California LCFS data and U.S. EPA GHG Emission Factors Hub for Scope 1 and 2 GHG emissions for each technology per the GHG Protocol. LCFS data is based on CA-GREET3.0. All fuels account for their respective energy efficiency ratio. Only CO_2 emissions from renewable fuels are deducted from Scope 1 emissions per the GHG Protocol accounting for biogenic emissions. California's modeling of CNG and RNG emissions assumes higher methane slip and therefore lower emission-reduction potential than EPA. Higher or lower emissions that are part of the fuel value chain would be captured in Scope 3 emissions. Renewable natural gas, biodiesel, renewable diesel, and hydrogen are the most relevant for Scope 3 emissions.

DIESEL VEHICLES

- Over the course of 2021, U.S. fleets saw the price of conventional diesel and gasoline fuel increase due to a range of factors. On-road diesel reached its highest price since late 2014.
- Fossil fuel was formally deemed to be incompatible with a sustainable global future by a 2021 Intergovernmental Panel on Climate Change (IPCC) Working Group report and 20 countries, including the U.S., agreed to end new direct public investments in international and unabated fossil fuels by the end of 2022.[31]
- Driven in part by government incentives such as the Renewable Fuel Standard (RFS) and various state-level clean fuel standards, RD is poised for big growth in the U.S., with biodiesel (BD) production declining.
- New ultra-low exhaust emission standards for HD vehicles adopted by California in 2021 may be unattainable for diesel engine technology without ancillary components which are costly and can reduce fuel economy.

MARKET SNAPSHOT

Globally, Governments Call for an End to Fossil Fuel Era

In 2021, fossil fuel was formally deemed to be incompatible with a sustainable global future by an Intergovernmental Panel on Climate Change (IPCC) Working Group report, authored by a body of more than 1,000 scientists worldwide that provide the data, science, modeling for the Conference of Parties (COP). COP represents the most structured, established, and recognized global authority on climate change data.

In 2021, fossil fuel was formally deemed to be incompatible with a sustainable global future by an Intergovernmental Panel on Climate Change (IPCC) Working Group report.

Finding clear evidence that GHG emissions from burning fossil fuels are threatening the planet and present existential risks to humanity, the United

[31] Abnett, Kate and Jessop, Simon, "U.S., Canada among 20 countries to commit to stop financing fossil fuels abroad," Reuters, 4 November 2021, accessed at https://www.reuters.com/business/cop/19-countries-plan-cop26-deal-end-financing-fossil-fuels-abroad-sources-2021-11-03/.

Nations (UN) Secretary General declared in no uncertain terms, "This report must sound a death knell for coal and fossil fuels, before they destroy our planet." The report specified that countries must end all new fossil fuel exploration and production, and shift subsidies to renewables.[32]

Governments Make Commitments at all Levels to Cut GHG Emissions from Transportation

Spurred in part by the 2021 UN Climate Change Conference (COP26), the Biden Administration worked aggressively to increase U.S. commitments on climate change mitigation.

In early December 2021, President Biden issued an Executive Order establishing national goals for procuring carbon-free electricity and declared that each federal agency must achieve a 100% ZEV acquisition standard by 2035, one of several moves to diminish the federal government's support of fossil fuels over the long term.[33]

Beyond leveraging the scale of the federal government's purchasing power, the Biden Administration and Congress are taking a multi-faceted approach to emissions reductions including providing significant funding under the IIJA and proposing new NOx and GHG emissions standards under the EPA's Clean Trucks Plan. The proposed standards are based in part on California's Low NOx Omnibus rule, a state regulation passed in late 2021 that requires trucks to comply with progressive emission reduction standards beginning in model year (MY) 2024.[34]

President Biden issued an Executive Order establishing national goals for procuring carbon-free electricity and declared that each federal agency must achieve a 100% ZEV acquisition standard by 2035.

Energy Majors Move Decisively into Clean Technologies

As governments and global agencies continue to declare that fossil fuels do not have a role in a sustainably managed future, several of the world's largest and most influential energy majors made moves to further diversify their portfolios.

Shell and bp have taken steps to diversify their businesses by acquiring electric vehicle service provider companies and investing in their respective charging networks' growth in the U.S. and E.U.

In mid-2021, three multinational oil and gas companies faced major actions pushing them to take responsibility for their burden of the climate crisis, take leadership in the clean energy transition, or both. Exxon shareholders appointed three board members put forth by climate activist investors; Chevron shareholders supported a motion to incorporate emissions from fuel sold in future reduction targets (Scope 3 emissions), against board wishes; and a Dutch court ordered Shell to cut GHG emissions by 45% by 2030, a more aggressive target than initially proposed by the oil company.

Collectively, oil and gas companies of all sizes are facing immense pressure to make significant and tangible commitments towards emissions reductions while increasing transparency around their activities to meet those commitments,

[32] United Nations, "Secretary-General Calls Latest IPCC Climate Report 'Code Red for Humanity', Stressing 'Irrefutable' Evidence of Human Influence," 9 August 2021, accessed at https://www.un.org/press/en/2021/sgsm20847.doc.htm.

[33] The White House Briefing Room, "FACT SHEET: President Biden Signs Executive Order Catalyzing America's Clean Energy Economy Through Federal Sustainability," 8 December 2021, accessed at https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/08/fact-sheet-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability/.

[34] California Air Resource Board Newsroom, "CARB passes "smog check" regulation for heavy duty trucks and buses," 9 December 2021, accessed at https://ww2.arb.ca.gov/news/carb-passes-smog-check-regulation-heavy-duty-trucks-and-buses.

while also generating financial returns for shareholders.[35] To that end, in the past few years Shell and bp have taken steps to diversify their businesses by acquiring electric vehicle service provider companies and investing in their respective charging networks' growth in the U.S. and E.U.[36,37,38]

National average prices at the pump were 19% higher in 2021 than in 2020; in mid-October, a gallon of diesel costs $1.20 more on average than at the same time the previous year.

Diesel and Gasoline Fuel and Vehicle Markets Experience Volatility and Disruption

Over the course of 2021, U.S. fleets saw the prices of conventional diesel and gasoline fuel increase due to a range of factors including supply shortages originating with the Organization of the Petroleum Exporting Countries (OPEC) and refinery closures. In May 2021, a cyberattack that brought down operations along 5,500 miles of Colonial Pipeline's service to the East Coast, the country's largest fuel pipeline, made national headlines and caused increased price instability.

On-road diesel prices reached their highest price since late 2014. National average prices at the pump were 19% higher in 2021 than in 2020; in mid-October, a gallon of diesel costs $1.20 more on average than at the same time the previous year. Gasoline prices followed a similar trend, exceeding their 2020 annual average by 29% and costing an average of $1.10 more per gallon in October than at the same time the year prior, exceeding $5 per gallon in some areas of California. The Alternative Fuels Data Center data shows that by the end of 2021, the average price of gasoline increased 49% in the fourth quarter of 2021 compared to the same quarter the previous year, with diesel jumping 46%.[39]

These trends accelerated in the first quarter of 2022 when Russia invaded Ukraine and several countries, including the U.S., introduced sanctions on Russian exports, driving the price of oil to more than $100 per barrel and average national diesel and gasoline prices to more than $5 per gallon in some areas of the country.

Engine and Fleet Efficiency Gains Continue to Advance, Explore Limits of Innovation

During the course of 2021, engine manufacturers, equipment manufacturers, and energy producers developed and tested innovative technologies with the goal of pushing the limits of efficiency and emissions reductions for diesel technology.

In mid-2021, Shell debuted the second generation of its ultra-efficient tractor, dubbed Starship 2.0. Its previous generation tractor from 2018 had already demonstrated efficiency of 2.48 times better than the national average on a ton-mile basis.[40] The new version maintained many of the aerodynamic features of the original, such as a carbon fiber body, with various improvements including a 2020 Cummins X15 engine. A 5,000-watt array of solar panels generates additional power for the main battery bank and hydraulic landing gear battery pack. A cross-country demonstration of a fully loaded Starship 2.0 from San Diego, California, to Jacksonville, Florida, achieved a fuel economy rating of 10.8 mpg with freight ton efficiency of 254 ton-miles per gallon.[41]

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[35] Lee, Julian, "The Day the World Changed for Big Oil," Bloomberg, 29 May 2021, accessed at https://www.bloomberg.com/opinion/articles/2021-05-30/exxon-shell-chevron-saw-the-world-change-for-big-oil-emissions.

[36] Greenlots, "Greenlots announces acquisition by Shell, one of the world's leading energy providers," 30 January 2019, accessed at https://greenlots.com/greenlots-announces-acquisition-by-shell-one-of-the-worlds-leading-energy-providers.

[37] bp Press Office, "bp takes first major step into electrification in the US by acquiring EV fleet charging provider AMPLY Power," 7 December 2021, accessed at https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-takes-first-major-step-into-electrification-in-us-by-acquiring-ev-fleet-charging-provider-amply-power.html.

[38] Chevron Corporation," Chevron Announces Agreement to Acquire Renewable Energy Group," 28 February 2022, accessed at https://chevroncorp.gcs-web.com/news-releases/news-release-details/chevron-announces-agreement-acquire-renewable-energy-group.

[39] Lockridge, Deborah, "Diesel Prices Spike," Heavy Duty Trucking, 14 October 2021, accessed at https://www.truckinginfo.com/10153938/diesel-prices.

[40] Hitch, John, "Shell Starship 2.0 propels fuel efficiency to greater heights," FleetOwner, 1 September 2022, Accessed at, https://www.fleetowner.com/emissions-efficiency/fuel-economy/article/21174002/shell-starship-20-propels-fuel-efficiency-to-greater-heights.

[41] Roeth, Mike, "Shell Starship 2.0 demonstrates improved efficiency," FleetOwner, 22 September 2022, accessed at, https://www.fleetowner.com/emissions-efficiency/fuel-economy/article/21176129/shell-starship-20-demonstrates-improved-efficiency.

Mesilla Valley Transportation Solutions, a national leader in fleet fuel efficiency, tested its aerodynamic fairing for Class 8 tractor-trailers, the EkoStinger, with a Cummins X15 15-liter engine and Eaton Endurant 12-speed automated manual transmission in November 2021. The combination of the one-piece polyethylene fairing, engine, and transmission resulted in a fuel savings of 5.72 gallons per 1,000 miles or 5%.[42]

Diesel Engines Needed Near-Term, May Never Meet Ultra-Low Emissions Standards

While diesel engine producers are under pressure to innovate further and faster, this dominant technology faces a clear physical limit in meeting and maintaining increasingly aggressive emission standards. Diesel engines today can meet California's MY2025 NOx emissions standard of 0.05 g/bhp-hr, however, the industry has not yet achieved the MY2027 NOx emission standard of 0.02 g/bhp-hr through design alone, nor as EPA-demonstrated technical feasibility. Similar NOx and GHG emission standards have since been proposed by the U.S. EPA under the Clean Trucks Plan. Manufacturers have observed that hardware and software changes must be paired with multiple aftertreatment systems to approach the 2027 standard — and that this negatively affects fuel efficiency, and thus TCO and GHG emissions.[43]

Manufacturers have observed that diesel engine changes needed to approach California's MY2027 standard
negatively affects fuel efficiency and TCO
of diesel vehicles.

While the road ahead for diesel engines will be paved with increasingly complex and costly technology requirements, market leaders have signaled that diesel engines will continue to play an important role during the decades-long transition to zero emissions. Engine manufacturer Cummins will invest in developing fuel agnostic internal combustion technology to serve all liquid and gaseous fuels.[44] Daimler Truck AG projects that 60% of its global sales will be ZEVs by 2030 and recognizes that it will continue to sell plenty of diesel engines through this time.[45,46,47]

Renewable Diesel Growth Very Strong, Adoption Led by Specific Fleet Types

Driven in part by government incentives such as the RFS and various state-level clean fuel standards, RD has a strong growth forecast in the U.S.

RD maintained an approximately $1/gal incremental cost over diesel nationwide in 2021, but in states with clean fuels programs such as California, its competitive price continued to support a growth in consumption. RD consumption in California increased approximately 50% between 2020 and 2021 to nearly 885 million gallons.[48]

Production capacity for RD increased from 600 to 800 million gallons per year between late 2020 and mid-2021, while projects that were under construction in July had the potential to add another billion gallons annually. By 2025, U.S.

[42] Newswire, "MVT Solutions Testing Reveals Fuel Savings for EkoStinger," Digital Journal Inc., 1 March 2022, accessed at https://www.digitaljournal.com/pr/mvt-solutions-testing-reveals-fuel-savings-for-ekostinger.

[43] California Air Resources Board, "SUPPLEMENT TO THE COMMENTS OF THE TRUCK AND ENGINE MANUFACTURERS ASSOCIATION," page 5, downloaded 7 February 2022, accessed at https://www.nj.gov/dep/njpact/docs/comments/ema-attach-20200910am.pdf.

[44] Cummins Inc., "CUMMINS' NEW LOW-CARBON FUEL-AGNOSTIC ENGINE PLATFORM STRATEGY," 14 February 2022, accessed at https://www.cummins.com/news/2022/02/14/cummins-new-low-carbon-fuel-agnostic-engine-platform-strategy.

[45] Presentation, "Daimler Truck Strategy Day", 20 May 2021, slide 40, accessed at https://group.mercedes-benz.com/dokumente/investoren/praesentationen/daimler-ir-presentation-daimler-truck-strategy-day-may-2021.pdf.

[46] Jones, Kevin, "U.S. long-haul fleets will shift to hydrogen: DTNA CEO," FleetOwner, 12 November 2021, accessed at https://www.fleetowner.com/equipment/trucks-trailers/article/21181083/us-longhaul-fleets-will-shift-to-hydrogen-dtna-ceo.

[47] Clevenger, Seth, "Volvo Trucks Outlines Next Steps Toward Carbon-Free Transport Vision," Transport Topics, 24 October 2021, accessed at https://www.ttnews.com/articles/volvo-trucks-outlines-next-steps-toward-carbon-free-transport-vision.

[48] California Air Resources Board, "LCFS Quarterly Data Spreadsheet - Quarterly Summary_013122", 1 March 2022, accessed at https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries.

production capacity is forecasted to exceed 5 billion gallons per year — enough to support 10% of the country's current diesel demand.[49]

Notably, Marathon Petroleum Corporation completed a test run of its RD refinery in Dickinson, North Dakota, in late 2021 and began ramping up to full production of 184 million gallons per year.[50] Marathon is also converting a refinery in Martinez, California, which is slated to become the second largest RD facility in the U.S., producing 730 million gallons per year of RD by 2023.[51]

In California, BD consumption increased a modest 9% since 2020 but occupied a smaller portion of the bio-based diesel market (25% compared to 31% in 2020), while RD became more dominant with 75% of the market share.

The U.S. EPA is considering a modification to the RFS program that would allow RD producers to receive renewable identification number (RIN) credits for using bio-intermediates, or renewable biomass feedstocks such as corn starch and soybean oil that are processed at one facility and transported to another to produce RD. If approved, RIN generation for use of these bio-intermediates could lower the costs for advanced RD production, making RD more affordable to consumers outside of California.

BD has not experienced the dramatic growth currently seen in the RD market — BD production capacity declined from 91 to 75 active facilities in 2021. A 58% increase in nine-month sales revenue from January 2021 to September 2021 was largely attributed to higher sale prices instead of volume.[52] BD is typically used as a blending fuel with diesel in low ratios (up to 20%) and fleets' demand is largely driven by state blending requirements. While these requirements remain steady, the demand is expected to remain steady. In California, consumption increased a modest 9% since 2020, but occupied a smaller portion of the bio-based diesel market (25% compared to 31% in 2020), while RD became more dominant with 75% of the market share.

The average price of B20 increased 17% year-over-year, reaching a peak of $2.74 in Q3 of 2021. While biofuel incentives remain strong, feedstock prices continue to increase due to international trade dynamics and domestic competition between the fuel and food industries. In the U.S., the price of soy rose dramatically in 2021 due to U.S. export/import dynamics, primarily with China.[53] Environmental groups remain critical of the incentives for increased domestic soy production due to the crop's negative environmental externalities.[54]

BD consumption in California has grown 131% since 2015 and 9% since 2020, maintaining an upward trend even as capacity declines.

Fleet Adoption and Insights: Renewable Diesel

In the annual fleet survey, RD adoption by fleets is high, especially among government fleets with nearly half of state, county, or municipal fleets (45%) reporting using RD. Nearly a quarter (23%) of regional goods movement fleets operating less than 250 miles per day reported using RD.

[49] Hill, Sean, et al., "U.S. renewable diesel capacity could increase due to announced and developing projects," U.S. Energy Information Administration, 29 July 2021, accessed at https://www.eia.gov/todayinenergy/detail.php?id=48916.

[50] Green Car Congress Newsroom, "Marathon Petroleum confirms successful test run for US refinery producing 100% renewable diesel based on Topsoe's HydroFlex," 6 August 2021, accessed at https://www.greencarcongress.com/2021/08/20210806-marathon.html.

[51] Reuters, "Marathon partners with Neste on Martinez renewable fuels project," 1 March 2022, accessed at https://www.reuters.com/business/sustainable-business/marathon-petroleum-partners-with-neste-martinez-renewable-fuels-project-2022-03-01/.

[52] Hill, Sean, et al., "U.S. renewable diesel capacity could increase due to announced and developing projects," U.S. Energy Information Administration, 29 July 2021, accessed at https://www.eia.gov/todayinenergy/detail.php?id=48916.

[53] International Agricultural Trade Report, "2021 U.S. Soybean Outlook Remains Strong After Record First Quarter Export Volume," Foreign Agriculture Service, U.S. Department of Agriculture, 29 June 2021, accessed at https://www.fas.usda.gov/data/2021-us-soybean-outlook-remains-strong-after-record-first-quarter-export-volume.

[54] Charles, Dan, "Biodiesel is booming. It may help the climate, but there's a big environmental risk," 28 October 2021, accessed at https://www.npr.org/2021/10/28/1043413986/biodiesel-is-booming-it-may-help-the-climate-but-theres-a-big-environmental-risk.

RD is even attractive to smaller fleets: 30% of small fleets with 11-50 vehicles report using RD, followed by 28% of larger fleets operating 100-1,000 vehicles. Fleet demand for RD in the future is very high, with 98% of fleets in the annual survey planning to use RD in the next 12 months.

Fleets that have used RD report operational perks. A vast majority of surveyed fleets that have used RD to replace diesel say that it provides equal or better performance on maintenance cost (95%). The effect is due to a high cetane number and other beneficial qualities that collectively enable HD vehicles to measurably reduce their engine-out NOx and PM emissions, respectively, while providing equivalent vehicle performance and near-equivalent fuel efficiency.[55] RD appears to improve performance and reduce life-cycle costs of diesel particulate filters, which are widely used to control PM emissions on post-2006 on-road HD vehicles (and some off-road HD vehicles).

While RD supply is growing substantially, cost and availability remain a challenge for surveyed fleets, with 43% of fleets reporting availability and 23% reporting cost as challenges to further adoption.

Fleet Adoption and Insights: Biodiesel

BD blends are common at low blending levels (5%, or B5) due to requirements by some agencies. For example, the Federal RFS requires oil refiners to blend billions of gallons of biofuels into the fuel mix or buy RINs from those that do, and states such as Minnesota and Pennsylvania have laws for minimum levels of blending.[56] Given these requirements, an estimated 62% of vehicles operated by fleets that participated in the annual survey report using some type of BD blend. Furthermore, more than half of private sector fleets (50%) report using BD blends.

> **"Biodiesel B20 provides many emission-reduction benefits with no challenges or changes to infrastructure required."**
>
> — Brendan King, Fleet Engineering Operations Manager, Salt River Project, Arizona

When asked about future use, three-quarters of fleets in our survey intend to use BD blends in the next 12 months, suggesting future demand that is higher than the ratio of fleets that have used this technology recently.

Logistics and goods movement fleets reported the highest adoption of BD at 34%; followed by state, county, or municipal fleets (excluding refuse and transit) at 28%, and regional logistics and goods movement fleets operating less than 250 miles per day at 27%.

According to the State of Sustainable Fleets annual survey, BD is most commonly used by fleets with more than 100 vehicles, with 27% of fleets with 100-1,000 vehicles and 28% of fleets with more than 1,000 vehicles using it. Among the barriers to adoption listed by users of BD blends, fuel cost led with 29% of users of drop-in BD blends citing it as a challenge.

Among existing users of clean technologies surveyed, growth in adoption is expected, with three-quarters of survey respondents intending to use BD blends in the next 12 months.

[55] Gladstein, Neandross & Associates, "Renewable Diesel as a Major Transportation Fuel in California: Opportunities, Benefits & Challenges," prepared for the South Coast Air Quality Management District and the Bay Area Air Quality Management District August 2017, accessed at https://www.gladstein.org/research/renewable-diesel-as-a-major-transportation-fuel-in-california-opportunities-benefits-challenges/.

[56] Alternative Fuels Data Center, "Biodiesel Laws and Incentives in Federal," U.S. Department of Energy, downloaded 7 February 2022, accessed at https://afdc.energy.gov/fuels/laws/BIOD?state=US.

Industry Perspective: Diesel Technology Forum

Diesel technology continues to dominate the commercial trucking sector, with truckers investing in more new diesel trucks than ever before. According to the most recent data from IHS Markit, as of December 2021, 53% of all commercial trucks in operation across the US are powered by the newest generation, 2011 and later model year (MY), advanced diesel technology; an increase of 4.2% over 2020.[i]

This is good news for communities and truckers. As older technology phases out, new technology diesel saves fuel and delivers timely, needed, progress on clean air as well as greenhouse gas (GHG) reductions. Compared to previous generations, this 2011 and later MY generation of diesel technology delivers a 98% reduction in nitrogen oxides and particulate matter emissions.[ii]

The next chapter for diesel technology is being written at the U.S. EPA right now with the Cleaner Trucks Initiative. It proposes to further reduce emissions from new diesel engines starting this year. Achieving further reductions in emissions will be achieved with technologies like cylinder deactivation, waste heat recovery, and more advanced emissions control systems.

Even as interest in zero emission technologies grows, diesel continues to dominate investments in the commercial trucking sector due to the combination of diesel's power and performance, efficient operation, lower cost of acquisition, well established nationwide fueling, as well as servicing and parts networks, among other factors.

The use of renewable diesel and biodiesel fuels offers an important and growing opportunity that ensures diesel's place in the future mix of powertrain options, offering fleets and communities a near-term and affordable decarbonization strategy; one that doesn't require new vehicles or fueling infrastructure. Last year in the US, about 3 billion gallons of biodiesel and renewable diesel fuels were produced, helping reduce GHG anywhere from 50 to 85%.[iii]

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[i] https://www.dieselforum.org/news/more-than-half-of-us-commercial-trucks-are-powered-by-near-zero-emissions-advanced-diesel-technology
[ii] https://www.epa.gov/emission-standards-reference-guide/epa-emission-standards-heavy-duty-highway-engines-and-vehicles
[iii] https://cleanfuels.org/news-events/news-releases/2022/03/16/biodieselday

PROPANE VEHICLES

- Propane continues to offer a very low fuel cost, remaining below $2 per gasoline-gallon equivalent, and more than 67% of fleets that use it report superior fuel cost in the fleet survey.
- Propane fuel demand in the transportation sector reached an all-time high in 2021, likely due to school re-openings and users of bi-fuel vehicles switching to propane due to high gasoline costs.
- Sales of propane vehicles declined for the second year, likely due to significant drops in demand in markets that were especially hard hit by COVID-19, such as school bus and paratransit.
- Cummins is introducing a new 6.7-liter engine signaling that the world's largest engine OEM continues to see a strong future for propane vehicles.
- Renewable propane remains a niche option for fleets, with fewer than 8% of propane users in the annual survey reporting availability, which indicates opportunity for market growth with increases in supply.

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

MARKET SNAPSHOT

Vehicle Sales Drop, Likely Linked to COVID-19 and Supply Challenges

Propane engine technology provides benefits for many fleets and continues to perform as a mature clean vehicle platform, especially in MD and school bus applications. However, vehicle orders declined 16% in 2021 and 23% in 2020, in no small part related to disruptions to manufacturer supply chains and operations caused by COVID-19. Acute parts shortages reduced OEM production, curtailing customer

deliveries and prompting some OEMs and aftermarket providers to close order books.[57] Demand decreased as fleets in school bus and paratransit sectors experienced lower ridership, limiting both wear and tear on their vehicles, as well as the revenue needed to support new vehicle purchases. Paratransit and municipal/utility fleet sectors were particularly impacted, and the sectors experienced decreases of propane vehicle sales of more than 60%.[58]

> **"Propane buses have saved the district thousands of dollars in terms of fuel cost and maintenance costs. In my experience, propane engines are an ideal fit for the stop-and-go school bus operations, especially in the colder climates we experience in Nebraska."**
>
> — Richard Casey, Director of Transportation, Bellevue Public Schools, Nebraska

There are, however, positive signs that demand may be increasing in certain segments. School bus sales for propane rebounded by 14% in 2021, and U.S. Postal Service contractors expect their use of propane trucks to continue to rise.[59] As production constraints ease, the delivery backlog will improve and customers can place orders that have been delayed, leading to more opportunities to replace vehicles that have been kept in service past their useful life.

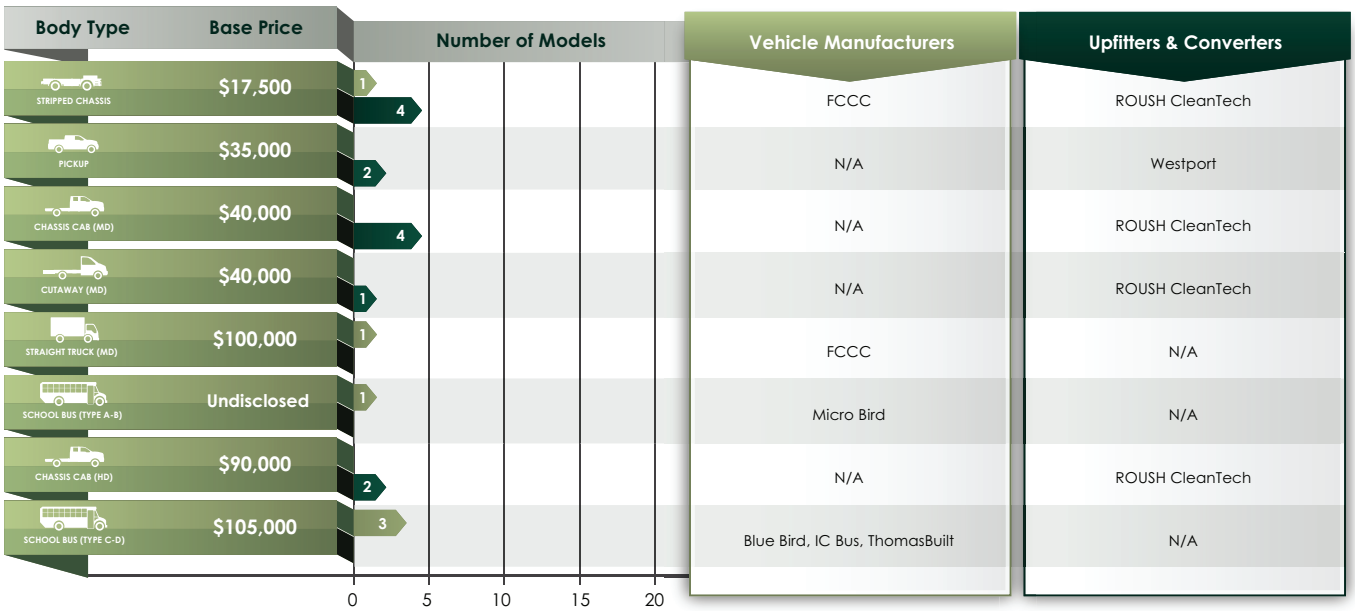
New Engine to Expand MD Applications

As part of Cummins' Destination Zero program, the new Cummins B6.7L propane engine will offer fleets a uniquely robust option for low-emission Class 7 applications, including beverage, school bus, and potentially future use in off-road markets, such as construction.[60] Using a standard cylinder design across its fuel-agnostic engines, Cummins intends to achieve efficiencies with production and vehicle fit so that OEMs can easily provide multiple engine options to meet customers' fuel needs without losing production efficiencies. The first engines under the Destination Zero program are due out for MY2024, although as of the writing of this market brief, the production timeline for the propane B6.7L has not yet been announced.[61]

Vehicle offerings saw very few changes from 2020 to 2021, further reinforcing manufacturers' focus on propane as a solution for MD and school bus fleets (Figure 3).

THE PROPANE VEHICLE MARKET

MD and HD Propane Vehicles (Limited to Full Production)



MD and HD Propane Vehicles (Announced to Active Demonstration)

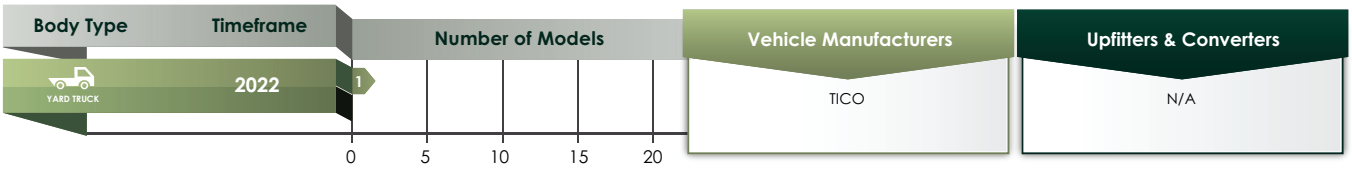


Figure 3: Propane vehicles offered by OEMs, upfitters, or converters producing new-build vehicles

Fuel Sales Peak, Fuel Demand Growth is Expected

Propane fuel demand in the transportation sector reached an all-time high in 2021, according to the Propane Education and Research Council (PERC), and experts claim that it could have been higher if vehicle production had met expectations. The peak is likely due to school re-openings that brought renewed demand from propane school buses and use of propane by bi-fuel vehicles switching from high-cost gasoline. The U.S. transportation fuel segment demand outlook remains strong, with annual growth estimates ranging between 3.8% and 9% during this decade.[62] Four states — California, Florida, Michigan, and Texas — accounted for about 30% of national demand for propane vehicle fuel, continuing a relatively consistent trend. Forecasts from PERC suggest that demand will grow broadly across the U.S. given the fuel's accessibility and affordability relative to other low-carbon fuel options.

> **"We have used propane for years and have found that it benefits our needs the most."**
>
> — Dr. Sheryl Alden, Director of Transportation, Denton Independent School District, Texas

> **Propane fuel prices have remained very competitive —**
> **below $2 per GGE**
> **— since 2020.**

For most fleets utilizing propane technology, private fueling remains the strategy of choice, for both cost and convenience. At least 90% of municipal and school fleets use private fueling, although the quantity of public fueling stations remains steady.[63] In fact, nearly two-thirds of propane users in the annual survey rely on their own private fueling (65%), and there is expansion of that infrastructure planned, with 33% of surveyed fleets that use propane intending to add new private infrastructure in the next 12 months.

Fuel Cost Remain Competitive Despite Price Increases

Although propane fuel prices increased in 2021, propane remains significantly more competitive than gasoline and diesel, and the overall cost of operating propane vehicles remains attractive. Propane prices jumped 125% as compared to

[57] GNA interview with Propane Education and Research Council (PERC) staff, 2 March 2022.

[58] GNA analysis of manufacturer sales estimates, provided by PERC.

[59] Lewis, Chris, "5 propane autogas fleets demonstrate the fuel's versatility," LP Gas Magazine, 18 October 2021, accessed at https://www.lpgasmagazine.com/5-propane-autogas-fleets-demonstrate-the-fuels-versatility/.

[60] Padmanabhan, Srikanth, "REDUCING COMMERCIAL TRANSPORTATION EMISSIONS TO REACH DESTINATION ZERO" Cummins, Inc., 17 February 2022, accessed at https://www.cummins.com/news/2022/02/17/reducing-commercial-transportation-emissions-reach-destination-zero.

[61] "New Cummins B6.7 Propane Autogas Engine Offers High-Performing, Low-Carbon Option," 3 March 2022, Propane Education & Research Council.

[62] EIN Presswire, "Propane Market Size is Expected To Reach USD 115.60 Billion By 2028, CAGR of 3.2%," Newswires, 18 March 2022, accessed at https://www.einnews.com/pr_news/565709691/propane-market-size-is-expected-to-reach-usd-115-60-billion-by-2028-cagr-of-3-2.

[63] State of Sustainable Fleets 2022 survey and the Propane Education and Research Council (PERC).

2020, reaching nearly $1.50 per GGE in October 2021.[64]

As 2022 began, energy market disruption added further upward pressure on the price of all transportation fuels. Prices for diesel and gasoline are expected to remain high for the foreseeable future. Yet, propane fuel prices have remained very competitive — below $2 per GGE —since 2020, thereby providing continued benefits for propane vehicle fleet operators. Propane's fuel price advantage is expected to stimulate market growth in the year ahead.

New Renewable Diesel Production Could Grow Renewable Propane Supply

The investment that will expand RD production throughout the country will also increase supply of its co-product, renewable propane, which can reduce GHG emissions by as much as 80%. For example, a new RD production facility in Bakersfield, California, will also produce 13 million gallons of renewable propane in its first year of operation.[65] The nation's largest retail propane marketer, AmeriGas Propane, has an agreement with the producer to purchase and distribute renewable propane from this plant.

The California propane industry has its own goal of transitioning to 100% renewable propane in the state by 2030. With renewable propane being chemically identical to traditional propane, it can be seamlessly integrated into the current propane distribution system and storage tanks and used in existing propane-powered vehicles. The drop-in nature of the fuel makes it easy for customers to switch to the renewable version of the fuel, as can be seen in U-Haul's recent agreement to sell renewable propane to its customers at 60 locations in California.[66]

> **"Our drivers have been pleased with the lower engine noise and cleaner emissions of our propane buses over our diesel buses. They are also impressed with the performance and ease of fueling."**
>
> — Robert Williams, Assistant Director of Fleet Services, Cypress Fairbanks School District, Texas

> **More than 35% of smaller fleets with 101-500 vehicles reporting use of propane vehicles.**

Despite industry interest, it is not yet clear that transportation will be the end-use for renewable propane. 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 or sale to other markets, as well as the benefits of sales in transportation to generate credits on low-carbon fuel markets like California's LCFS, will determine whether this technology can scale to aid fleets that use propane in realizing more significant GHG reduction benefits from switching to renewable propane.

Propane: Fleet Adoption and Insights

Across all clean vehicle fleets that have used one of four clean drivetrain technologies covered in the annual survey, only 20% of these early adopters have operated propane vehicles during the past two years. The use of propane vehicles is concentrated in only a few sectors, with 43% of state, county, and municipal fleets included in the State of Sustainable Fleets annual survey reporting using propane vehicles, followed

[64] GU.S. Energy Information Administration, "Petroleum & Other Liquids," downloaded 7 February 2022, accessed at https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EER_EPLLPA_PF4_Y44MB_DPG&f=M.

[65] Business Wire Newsroom, "Global Clean Energy Holdings and UGI Announce Partnership to Distribute Renewable LPG," 15 February 2022, accessed at https://www.businesswire.com/news/home/20220215005548/en/Global-Clean-Energy-Holdings-and-UGI-Announce-Partnership-to-Distribute-Renewable-LPG.

[66] Bemer, Carly, "Suburban Propane, U-Haul extend renewable LPG agreement," LP Gas Magazine, 7 October 2021, accessed at https://www.lpgasmagazine.com/suburban-propane-u-haul-extend-renewable-lpg-agreement/.

by shuttle operators (22%) and transit agencies (20%). For the first time since beginning the annual fleet survey, fewer than half of school district fleets (14%) indicated propane use, perhaps reflecting arrested use of all transportation by schools during COVID-19.

Propane adoption is more common among small and midsize fleets. Smaller fleets, those with 101-500 vehicles, lead among fleets when grouped by size, with more than one-third (35%) reporting its use, followed by fleets with 1,001-10,000 vehicles (28%). Among all other fleet sizes that were assessed, fewer than 5% of respondents reported using the technology.

Fleets that have piloted or purchased propane in the past 24 months confirm that the fuel provides reduced cost benefits among other positive operational gains (Figure 4). Most fleets that have piloted or purchased propane vehicles report equal or better performance on emissions (92%), noise (88%), fuel cost (86%), and odor (84%).

There are some challenges to wider fleet adoption of propane vehicles and those main concerns are vehicle cost and range, which were both cited as issues by 51% of fleets operating on the fuel. However, the sustained lower cost of fueling with propane as compared to gasoline helps fleets offset vehicle cost, resulting in 47% of propane users in our survey citing TCO as an advantage. Weighing all these factors, many fleets that currently use propane are planning to continue to do so, with more than half of current propane users in the survey (57%) intending to purchase more propane vehicles in 2022.

> **"Propane-powered vehicles are lower maintenance, cleaner emissions, and lower cost."**
>
> — Laurie A. Cleaver, Director, Ottawa County Transportation Agency, Ohio

PERFORMANCE AND ADOPTION RESULTS REPORTED BY PROPANE USERS

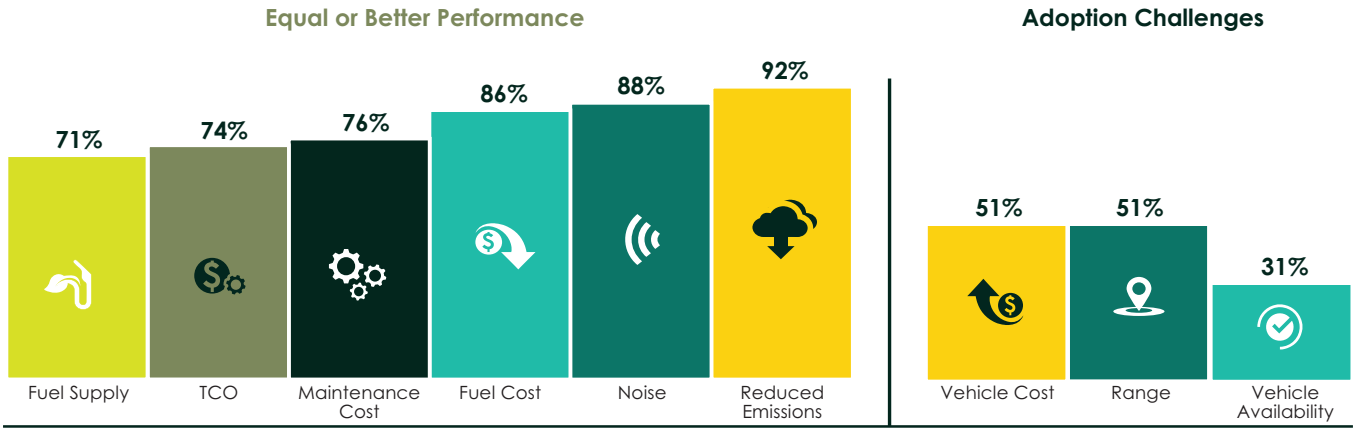


Figure 4: Percentercent of propane users surveyed who cite a criteria as equal/better or an adoption challenge compared to diesel and gasoline.

As noted above, the use of renewable propane is expected to climb in the years ahead. Presently, only about 8% of fleets operating propane vehicles report using renewable propane in the past two years. However, 29% of fleets in the survey reported they will implement renewable propane in the next 12 months if they can secure supply. With the supply of renewable propane expected to expand in 2022, this increased market demand could be satisfied. Further, given the growing number of public and private fleets adopting increasingly ambitious sustainability goals, and with 92% of surveyed propane vehicle users recognizing the emissions reductions benefit of propane, demand from fleets for a lower carbon version of the fuel should remain strong.

Industry Perspective: Propane Education and Research Council (PERC)

Propane continues to be the proven alternative fuel leader in school transportation with 22,000 buses on the road in more than 1,000 school districts across 48 states. Propane buses reduce overall operational costs while safely and reliably carrying 1.3 million children to school each day. Today's propane engine technology meets or exceeds customer expectations for payload, range, and torque. As part of the near-zero alternative fuel options available for funding as part of the U.S. EPA's Clean School Bus Program, propane school buses offer significant reduction in nitrogen oxide, particulate matter, and carbon dioxide emissions at a fraction of the cost of electric models. And propane's affordable, scalable infrastructure can be installed quickly in virtually any location.

Propane has a proven track record of delivering on investment. In fact, school districts have delivered more propane buses at a fraction of the investment than all other alternatives combined through the Volkswagen Environmental Mitigation Settlement Fund.[67]

Propane's performance is not limited to school transportation. Propane continues to drive the Class 3-7 market with gains in paratransit, postal contractors, delivery, and food and beverage. In February, Cummins announced its exciting new B6.7L propane offering. In testing, the Cummins B6.7 propane engine delivered the lowest GHG emissions of any propane-powered engine and will deliver some of the lowest GHG emissions in the MD market.[68] The Cummins B6.7 propane engine offers a path to decarbonization without compromising on performance or range. Fleet owners also benefit from diesel-like durability, reliability, and high uptime. This latest, innovative engine technology demonstrates propane's role in a near-zero future in the MD market.

Not only is engine technology improving, but the fuel is also changing. Renewable propane has the same great features as conventional propane — reliability, portability, power — but with even lower carbon intensity when compared with other energy sources. The most common form of renewable propane is a byproduct of renewable diesel and sustainable aviation fuel made primarily from plant and vegetable oils, animal fats, or used cooking oil. In on-road vehicle tests conducted by the University of California Riverside, renewable propane was a drop-in replacement for conventional propane. It offered the same low nitrogen oxide and particulate matter reductions, while improving lifetime carbon dioxide emissions reductions.[69] Several U.S. refineries in California, Texas, and Louisiana have existing capacity to produce renewable propane as part of their renewable diesel production systems, and U.S. production of renewable diesel is projected to increase almost ninefold from 2020 to 2024.[70]

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[67] Volkswagen Diesel Emissions Environmental Mitigation Trust, "PERC analysis of compiled data reported by states and tribal communities as well as settlement entities at the state level," downloaded 7 February 2022, accessed at https://www.vwenvironmentalmitigationtrust.com/.

[68] Metro Magazine, "New Cummins Propane Autogas Engine Offers Low-Carbon Option," 3 March 2022, accessed at https://www.metro-magazine.com/10162700/new-cummins-propane-autogas-engine-offers-low-carbon-option.

[69] Li, Chengguo, et al., "On-Road Testing of an LPG Delivery Truck on R-LPG: Final Report," University of California, Riverside, College of Engineering-Center for Environmental Research and Technology, Riverside, CA, September 2020.

[70] Atlantic Consulting bioLPG report, NREL biopropane analysis, US EIA.

NATURAL GAS VEHICLES

- In California, RNG production and consumption grew, with low- or negative-carbon RNG making up 98% of CNG for transportation in the state.
- In 2021, the average carbon intensity of all the natural gas reported in the California LCFS was below zero, making NGVs the only carbon-negative transportation option for fleets.
- Cummins announced a new 15-liter NZE natural gas engine, the X15N, that is more powerful and lighter than the current Cummins 12-liter engine. It will enable even the heaviest of work trucks — including long-haul trucks and liquid tankers — to adopt CNG and is expected to increase fleet adoption.
- Throughout 2021, CNG maintained a clear cost advantage and relative price stability compared to diesel fuel. On average, diesel fuel was 25% higher than CNG, although the spread increased from 10% to nearly 30% between January and mid-October.[71,72]
- Transit buses, straight trucks (including refuse), and Class 8 tractors continue to dominate NGV sales, which helped to show a small growth in 2021 sales compared to 2020.

THE FLEET TYPES LEADING CNG VEHICLE ADOPTION

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

Estimated Medium- and Heavy-Duty Vehicles in Operation

TENS OF THOUSANDS — THOUSANDS

[71] Alternative Fuels Data Center, "Average Retail Fuel Prices in the United States," U.S. Department of Energy, Excel download accessed on 7 January 2022, https://afdc.energy.gov/fuels/prices.html.

[72] Alternative Fuels Data Center, "Clean Cities Alternative Fuel Price Report", U.S. Department of Energy, Table 13c, January-October 2021 issues, downloaded 7 February 2022, accessed at https://afdc.energy.gov/publications/search/keyword/?q=alternative%20fuel%20price%20report.

MARKET SNAPSHOT

Cummins Announces Larger Engine, Opening Door to CNG for New Fleets

In an effort to expand the use of CNG in HD applications, Cummins announced plans in October 2021 to release the X15N, a 15-liter natural gas engine for MY2024. Calling it a "cost-competitive power option" for fleets looking to replace their HD diesel fleets, the manufacturer's new 15-liter engine replaces its 12-liter (being discontinued in 2025) by offering greater cylinder displacement, horsepower, and torque without increasing the engine's physical size, and even shaving 200 lbs. off the product weight. Since the X15N has a similar footprint as the 12-liter Cummins natural gas engine, many truck OEMs will not need to invest significant incremental engineering time or cost to be able to offer trucks with this platform. This lighter and more powerful engine will allow fleets operating in traditional over-the-road long-haul and heavy-haul applications to take better advantage of the operational, environmental, and cost performance benefits offered by natural gas.

> **"Having CNG at our fueling station has been a great choice for our city, maintenance cost are a great deal cheaper because of extended time between performing preventive maintenance. Plow trucks have performed as well with CNG as they do with diesel fuel — huge savings in fuel cost."**
>
> — John Hyatt, Fleet Manager, City of Dublin, Ohio

As part of the company's Destination Zero strategy, Cummins will develop its B-, L-, and X-Series engines with a fuel-agnostic approach. Dedicated variations of each engine will be designed to support diesel, natural gas, or hydrogen fuel. This will be accomplished using a single engine block and common core components but different fuel systems and parts above the head gasket for the different fuel options to create production efficiencies and potentially reduce cost differences between the end vehicle types. This strategy will allow Cummins to not only offer the X15N in a natural gas configuration but in an internal combustion hydrogen version as well, creating a possible bridge for the trucking industry to meet potential ZEV standards in the future.

The announcement of the X15N was met with very strong fleet customer interest, with dozens of over-the-road fleets asking to take part in the field trials. Ultimately, Cummins announced that Werner Enterprises would be participating in the initial field trials in the first half of 2022. It was also announced that Werner will test the hydrogen version of this 15-liter Cummins engine at a future date.[73]

RNG Nearly Replaces Fossil CNG in California, Production Growing Nationally

RNG has made a leap forward in states like California where it has become the dominant form of CNG consumed by the transportation industry. According to data reported into California's LCFS program, RNG made up 98% of total natural gas vehicle fuel consumption in 2021 (up from 92% in 2020), with traditional CNG contributing the final 2%. Nationwide, 64% of natural gas fuel used in on-road transportation in 2021 was RNG, according to Natural Gas Vehicles America.[74]

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[73] Cummins, Inc., "U.S. logistics leaders to add Cummins' new natural gas & hydrogen engines," NGV Journal, 28 January 2022, accessed at http://www.ngvjournal.com/s1-news/c1-markets/u-s-logistics-leader-will-integrate-cummins-new-natural-gas-and-hydrogen-engines/.

[74] Natural Gas Vehicles America, "Decarbonize Transportation with Renewable Natural Gas," May 2022, accessed at https://ngvamerica.org.

According to California's LCFS program, RNG made up 98% of total natural gas vehicle fuel consumption in 2021 (up from 92% in 2020).

On the supply side, RNG production capacity increased by 24% from 2020 to 2021, enabling the U.S. to produce enough RNG fuel to displace nearly 574 million gallons of diesel annually.[75] RNG was about 30% of Clean Energy Fuels' total CNG deliveries in 2021, a ratio that was nearly constant between 2020 and 2021.[76]

In September 2021, Shell began producing RNG at its first U.S. biomethane facility in Oregon. The company aims to produce 736,000 MMBtu per year of RNG for HD on-road transportation consumption, equivalent to more than 5 million DGE. Shell is also developing production facilities in operating dairies in Kansas and Idaho, for an estimated 900,000 MMBtu, or more than 7 million DGE, per year.[77]

"We continue to see renewable natural gas vehicles as the best current solution to meet range, fueling, and emissions reduction requirements."

— Matt Harris, Sustainability Area Manager, Wegmans Food Markets, New York

US Gain supported the development of two new landfill gas-to-RNG facilities in 2021, with one opening in July to support Republic Services' fueling needs in Houston, Texas.[78] Another facility is under construction in South Carolina that will support the local department of public works.[79] US Gain also announced that its RNG supply will be a feedstock for hydrogen production in the California transportation market.[80] Renewable feedstocks for hydrogen fuel for transportation increase its value in the LCFS market.

As of December 31, 2021, 230 RNG projects were projected to be in operation across the U.S. — 46% more than in 2020. One-third of the RNG produced was intended only for vehicle fuel consumption, while the remainder was injected into pipelines for a variety of uses (e.g., heat, power, transportation). California continues to rank first in terms of number of operational RNG projects; the state saw an 85% growth in 2021 — from 40 projects to 74.[81]

Two states are leading the way in terms of RNG production, but with different approaches. Texas tops the list with the most landfill gas projects, while California has the most agriculture projects. As of 2021, California only has one operational landfill gas project and Texas has yet to operate any agricultural projects.[82] Agricultural RNG, especially from swine and dairy manure, has the lowest carbon intensity and therefore garners top dollar on California's LCFS market.

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[75] Mintz, M. and Vos, P, Database of Renewable Natural Gas (RNG) Projects: 2021 Update, Argonne National Laboratory, January 2022, accessed at https://www.anl.gov/es/reference/renewable-natural-gas-database.

[76] Clean Energy Fuels Newsroom, "Clean Energy Reports 104.5 Million Gallons Delivered and Revenue of $91.9 Million for the Fourth Quarter of 2021," 24 February 2022, accessed at https://investors.cleanenergyfuels.com/news-releases/news-release-details/clean-energy-reports-1046-million-gallons-delivered-and-revenue.

[77] Business & Industry Connection Magazine, "Shell fires up new RNG facility," 30 September 2021, accessed at https://www.bicmagazine.com/projects-expansions/downstream/shell-fires-up-new-rng-facility/.

[78] U.S. Gain Newsroom, "Ameresco Reaches Commercial Operation of Landfill Gas to Renewable Natural Gas Plant," 15 July 2021, accessed at https://www.usgain.com/news/ameresco-reaches-commercial-operation-of-landfill-gas-to-renewable-natural-gas-plant/.

[79] U.S. Gain Newsroom, "The Landfill Group, LS Power announce South Carolina RNG project," 9 September 2021, accessed at https://www.usgain.com/news/the-landfill-group-ls-power-announce-south-carolina-rng-project/.

[80] U.S. Gain Newsroom, "U.S. Gain Enters First of its Kind Partnership to Supply RNG into Hydrogen Production," 8 February 2022, accessed at https://www.usgain.com/news/u-s-gain-supplies-rng-into-hydrogen-production/.

[81] Mintz, M. and Vos, P., "Database of Renewable Natural Gas (RNG) Projects: 2021 Update", Argonne National Laboratory, January 2022, accessed at https://www.anl.gov/es/reference/renewable-natural-gas-database.

[82] Mintz, M. and Vos, P. Database of Renewable Natural Gas (RNG) Projects: 2021 Update, Argonne National Laboratory, January 2022, https://www.anl.gov/es/reference/renewable-natural-gas-database.

The trend is expected to continue nationally and become a larger share of total biofuel production, in line with global projections by the IEA that RNG production is expected to grow from 1% of global biofuel production in 2020 to nearly 20% by 2050, becoming one of the fastest-growing types of fuel within the segment.[83]

Emissions Reductions in RNG Supply Continue to Decline, Remain Negative in California Throughout 2021

In California, RNG's carbon intensity (CI) continued its downward trend into negative numbers over the course of 2021. The energy weighted carbon intensity of all natural gas consumed in California for all of 2021 was -33.36 gCO2e/MJ, down from the -27.17 through the first three quarters of 2021.[84] This trend is expected to continue in 2022 and beyond.

> **"The use of CNG and RNG has greatly reduced our emissions and increased driver satisfaction."**
>
> — John Lee, Senior Fleet Analyst, U.S. Foods, Illinois

Growth in the volume of swine and dairy gas being reported into the state's LCFS program is the main factor driving the CI value of natural gas transportation fuel lower. For fleets working to reduce GHG emissions, using carbon negative RNG can provide significant sustainability benefits, while simultaneously allowing fleets to achieve substantial fuel cost savings.

In May 2021, Chevron and Clean Energy Fuels launched their Adopt-a-Port initiative with $28 million in funding to provide carbon-negative RNG to large trucking fleets and owner-operators serving the San Pedro Bay Ports.[85] After ordering hundreds of NGVs in Q1 of 2021, Amazon signed a deal with Clean Energy Fuels for both low- and negative-carbon RNG at 27 existing fueling stations and an additional 19 non-exclusive new or upgraded stations, which Clean Energy planned to construct in 2021 and 2022.[86]

RNG is favored by fleets for its environmental and economic sustainability benefits, as the cost of this very low-carbon — and sometimes carbon-negative — fuel is typically at or below the cost of traditional natural gas, as is the case in California due to the LCFS market. In the State of Sustainable Fleets annual survey, around 60% of CNG users confirmed that they are currently using RNG, showing both its success in the market and the growth opportunity that remains.

CNG Maintains Cost Advantage Over Diesel During Volatile Year

Throughout 2021, CNG maintained a clear cost advantage and relative price stability when compared to a volatile year for diesel. The clean fuel continued to prove its value, with the price of CNG increasing approximately 3% on average at public fueling stations compared to 2020. Diesel prices increased nearly 19% nationwide and were, on average, 25% higher than the price of CNG on a DGE basis.[87] Fuel cost is a primary benefit of CNG users in the annual fleet survey with 79% reporting it as an advantage of the technology.

For fleets with private, on-site fueling infrastructure, prices increased 12% in 2021, compared to about 3% the previous year.[88] Fleets with private fueling have historically realized substantial savings as compared to public propane fueling, but that

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[83] Patrick Newkumet, "IEA Sees Need for Jump in Advanced Biofuel Output to Reach Carbon Neutrality," Oil Price Information Service, 18 May 2021.

[84] GNA analysis of RNG carbon intensity from quarterly CARB reports on emission trading for 2021, accessed at https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries.

[85] Alford, Aaron, "Chevron Invests Additional $20 Million in Southern California RNG Initiative," OPIS Net, 11 May 2021.

[86] Ibid.

[87] Alternative Fuels Data Center, "Publications," U.S. Department of Energy, April 6, 2022, accessed at https://afdc.energy.gov/publications/search/keyword/?q=alternative%20fuel%20price%20report.

[88] Alternative Fuels Data Center, "Fuel Prices," U.S. Department of Energy, downloaded 7 February 2022, accessed at https://afdc.energy.gov/fuels/prices.html.

gap decreased in 2021. The savings that fleets realize from private fueling instead of public fueling dropped by about 50% even while the per DGE pump price remained competitive at $2.32 per DGE for private fuelers versus $2.57 per DGE at public fueling stations.[89]

Natural Gas Fueling Station Count Remains Steady While Fuel Consumption Increases

The ongoing trend of natural gas fueling station closures continued in 2021, with a 6% closure of public and private stations as reported by the Alternative Fuel Data Center.[90] However, 13 public stations designed to support HD vehicles across the West and South were in the planning stage as of February 2022. While natural gas fueling infrastructure numbers have declined slightly, CNG fuel sales increased 8% nationally, recovering from a 4% decline between 2019 and 2020. Total consumption in this segment has grown 25% since 2015, suggesting a concentration of fuel use among fewer stations.[91] This is likely a result of the growth of the HD CNG market and a waning of the LD CNG vehicle market since the mid-2010 period. As the U.S. Energy Information Administration's survey methodology will begin tracking RNG and CNG separately starting in 2022, better data on the national use of RNG is expected to result end enable validation of year-over-year growth.

Transit, Straight Truck, and Tractors Continue to Dominate Sales, Sustain Growth

NGV registrations increased 3% in 2021, to 6,477, a slightly higher growth than in 2020, when delivery growth was around 2%.[92] Tractor trucks were the strongest growth segment, with a 94% increase to 3,013 in 2021 versus 1,550 in 2020. Both Amazon and UPS have made large, multi-year purchases that are likely driving this number.[93,94] Transit bus deliveries increased 22% with 1,033 vehicles registered in 2021 versus 848 in 2020.

Tractor trucks were the strongest growth segment, with a
94% increase to 3,013 NGV registrations
in 2021 versus 1,550 in 2020.

Straight trucks were the second-largest segment of NGVs, with 2,166 units delivered in 2021. According to DMV registration data provided by IHSMarkit, many of these vehicles — 1,295 identified vehicles — were for refuse applications. The number is likely low due to registration and delivery data lagging on several large orders, including purchases of around 1,000 CNG vehicles by WM, which operates the largest HD natural gas truck fleet of its kind in North America, with more than 10,300 CNG trucks in operation and more than 170 natural gas fueling stations.[95]

The school bus segment has seen a steady decline in new CNG buses since 2017, with a sharp drop of 64% in 2021 — only 69 new CNG buses were registered, compared to an average decline of 20-30% year-over-year since 2017. This is likely due to the continued competitive TCO of propane school buses, a general reduction in school bus activity due to the COVID-19 pandemic, and an increase in the level of attention and funding being directed to battery-electric school buses.

Cargo and passenger van purchases also declined significantly — 96% for cargo vans and

[89] Alternative Fuels Data Center, "Clean Cities Alternative Fuel Price Report," U.S. Department of Energy, October 2021, accessed at https://afdc.energy.gov/files/u/publication/alternative_fuel_price_report_october_2021.pdf Table 13.c.

[90] Ibid

[91] U.S. Energy Information Administration, "Short-Term Energy Outlook," September 2021, https://www.eia.gov/outlooks/steo/.

[92] State DMV data provided by IHS Markit. Registrations are considered a reliable indicator of orders and a better indicator that most sales data that are used to understand trends in other technologies. State-level DMV data do not track most NZ and ZE data except for CNG.

[93] Sanicola, Laura, "Amazon orders more than 1,000 natural gas engines for U.S. truck fleet," Reuters, 5 February 2021, accessed at https://financialpost.com/commodities/energy/amazon-orders-more-than-1000-natgas-engines-for-u-s-truck-fleet-2.

[94] Green Fleet Staff, "UPS Adding 6,000 Natural Gas Vehicles," 9 October 2019, accessed at https://www.greenfleetmagazine.com/342152/ups-adding-6-000-natural-gas-vehicles.

[95] California Natural Gas Vehicle Partnership Newsroom, "Waste Management," downloaded 7 February 2022, accessed at https://cngvp.org/wp-content/uploads/2022/01/CNGVP-OneSheet-8-5x11-WM-FINAL.pdf.

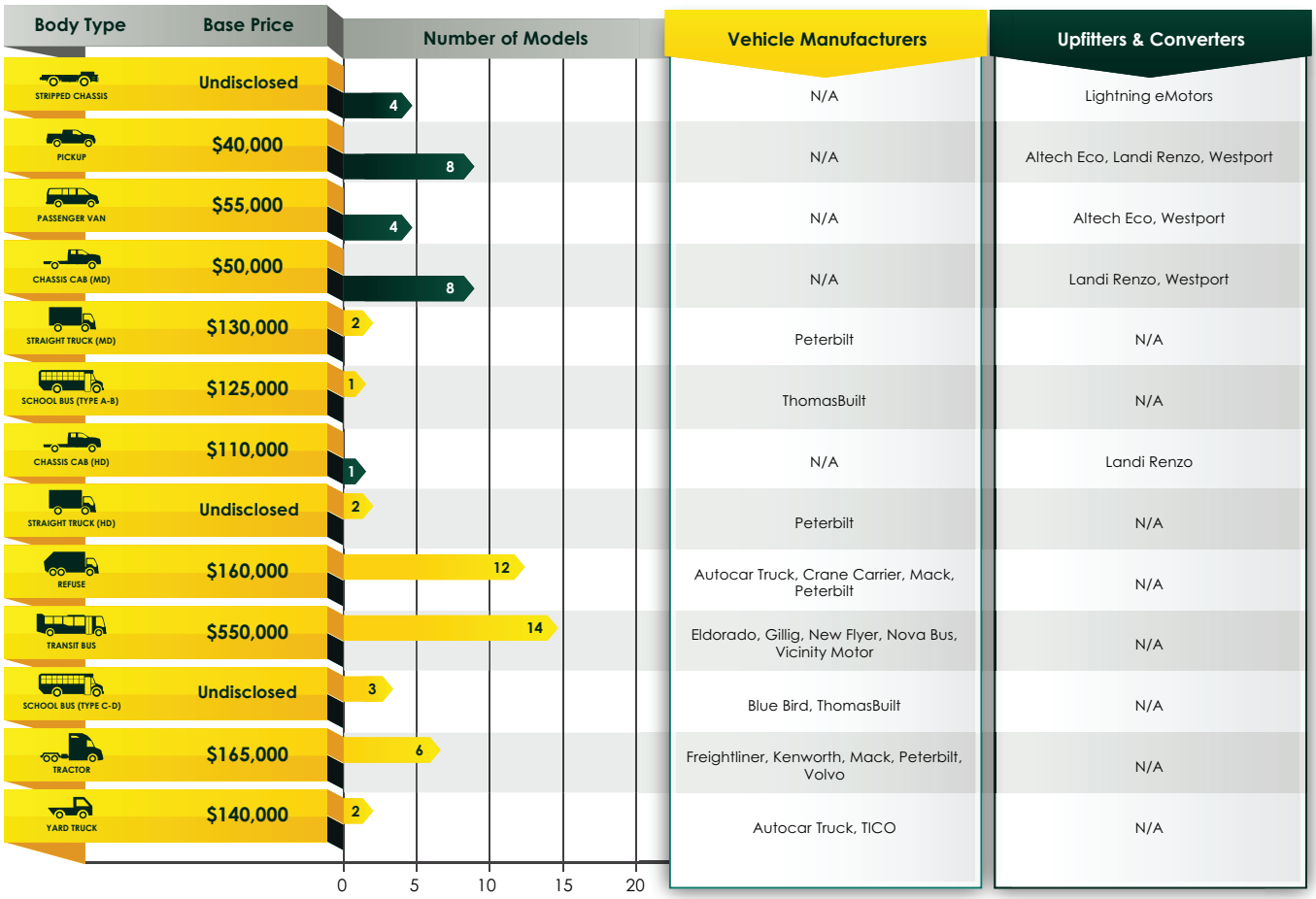
67% for passenger vans. This was triggered by GM's removal of most of its vehicle offerings in this segment at the start of 2021.

Currently, there are 70 MD and HD NGV models commercially available from OEMs (Figure 5). Refuse and transit bus models are the most common, with more than 10 models available from manufacturers in each category. GNA's review of publicly available data from three transit bus manufacturers show that the capital cost of HD CNG transit buses declined approximately 10% in 2021, making them even more competitive with diesel buses.

In the yard truck segment, two models are available for purchase, while the MD segment, which includes chassis cabs and pickups, has the largest numbers of offerings, all from upfitters. Overall, MD models declined 40%, with GM's exit causing the biggest drops in cab-over, cutaway, passenger shuttle, and pickup models.

THE NATURAL GAS VEHICLE MARKET

MD and HD Natural Gas Vehicles (Limited to Full Production)



MD and HD Natural Gas Vehicles (Announced to Active Demonstration)

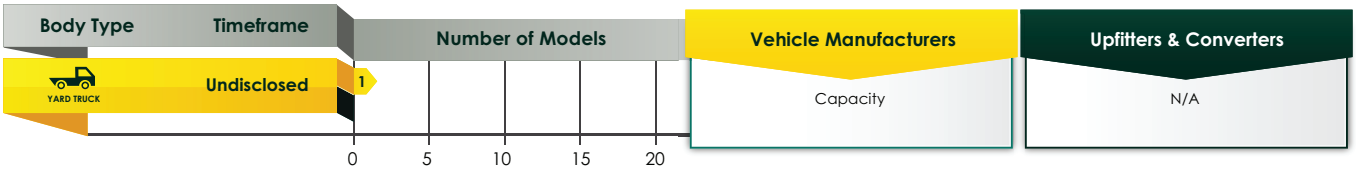


Figure 5: CNG vehicles offered by OEMs, upfitters, or converters producing new-build vehicles

NGV: Fleet Adoption & Insights

Among early adopters of the four drivetrains that the State of Sustainable Fleets report assesses annually, just under half (45%) have operated CNG vehicles in the past two years. However, CNG is also the alternative drivetrain with the greatest overall uptake by vehicle count. Among all clean technology vehicles operated by early adopters surveyed in 2021 (diesel engines using BD, RD, or any clean drivetrain), 20% are CNG vehicles, speaking to the technology's use at scale by a significant number of individual fleets and fleet types that see sustained cost and performance benefits.

> **"CNG has been an excellent decision for our Sanitation fleet. Decreased down time. Reliable fuel. Quiet trucks with far less emissions."**
>
> — City of Olathe, Josh Wood, Fleet Manager, Kansas

Looking closer at the breakdown of CNG early adopters surveyed, just over one-third of state, county, and municipal fleets (32%), as well as nearly one-third of transit fleets (28%), have operated CNG vehicles in the past two years. Also, close to one-quarter of refuse fleets (24%) surveyed have operated CNG vehicles in the past two years. Across all CNG vehicles operated by fleets in the annual survey, two fleet types account for nearly half of all vehicles, with refuse and Class 8 tractors operating in the mail and package delivery sector representing 40% of all vehicles. These figures suggest the technology has found a strong foothold with these fleet types and opportunity for growth to similar fleet types.

As reported above, many of the nation's largest fleets have made major investments in NGVs, a finding that is also reflected in the annual fleet survey, with 64% of all CNG vehicles in the survey represented by fleets with 10,001-100,000 vehicles, followed by another 24% of CNG vehicles represented by fleets with 1,001-10,000 vehicles. With natural gas fuel prices consistently well below diesel, and NGVs becoming more cost-competitive, there is growing evidence that small and midsize fleets also find value in the technology. One-quarter of all fleets surveyed that operate 101-500 vehicles have used CNG in the past two years, followed by 11% of fleets with 51-100 vehicles. Just under two-thirds of CNG vehicle operators in the annual survey (64%) intend to purchase additional CNG vehicles in 2022.

As an example, National Ready Mixed Concrete Company deployed another 24 NZE concrete mixers from Peterbilt in 2021, expanding its Southern California CNG fleet to 117 natural gas trucks.[96] This mirrored the continued growth seen with CalPortland's 24 NZE truck order in late 2020, adding to an existing fleet of 118 natural gas units.[97] With new engine technology coming to the market and increased focus on sustainability in the construction industry, this high fuel use segment is expected to continue to grow its use of CNG trucks.

Most fleets that have piloted or purchased CNG in the past two years report equal or better performance on emissions (96%), fuel cost (89%),

> **"CNG buses have been a successful implementation in technology and provide a significant fueling cost benefit."**
>
> — Daniel Dietrich, Director of Fleet Management, Greater Cleveland Regional Transit Authority, Ohio

[96] A California Natural Gas Partnership, "National Ready Mixed Concrete Company Expands its Carbon-Negative Fleet in Southern California," Yahoo! News, 23 June 2021, accessed at https://www.yahoo.com/now/national-ready-mixed-concrete-company-153000237.html.

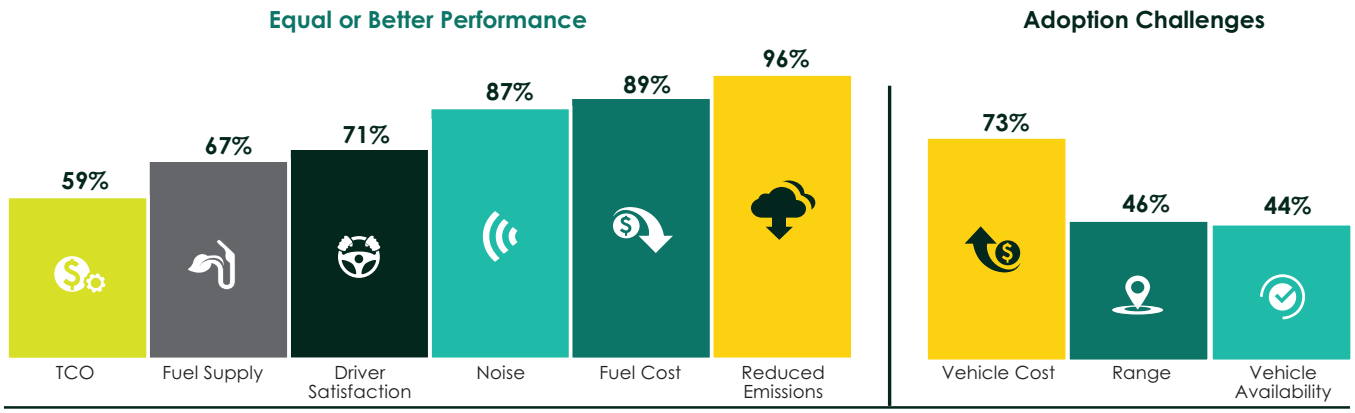
[97] NGV Global Group News Room, "CalPortland Taps CNG to Fuel Bulk Hauler Truck Fleet," 20 December 2020, accessed at, https://ngvglobalgroup.com/calportland-taps-cng-to-fuel-bulk-hauler-truck-fleet/.

noise (87%), driver satisfaction (71%), and fuel availability (67%) as compared to diesel (Figure 6).

The level of investment in the MD and HD NGV market compared to the availability of NGV grant programs suggests that most of the fleet investment in NGVs is happening without the use of incentive funding. More than half (57%) if fleets in our survey that have used CNG report equal or better TCO. This speaks to the commercial maturity of the technology, as well as a demonstrated ROI for end users. The top challenge stated by CNG early adopters is vehicle cost, reported by 73% of CNG users in the annual survey, followed by technology availability and range.

PERFORMANCE AND ADOPTION RESULTS REPORTED BY CNG USERS

Percent of CNG users surveyed who cite a criteria as equal/better or an adoption challenge compared to diesel and gasoline.



Source: Percent of surveyed early adopter fleets that have either piloted or purchased MD or HD CNG vehicles who cite a criteria as either equal/better or a challenge from the State of Sustainable Fleets 2022 survey.

Figure 6: Performance and adoption results reported by CNG users in the annual fleet survey

A majority of CNG users (70%) in the annual survey use private fueling infrastructure. The use of private or priority-access, semi-private fueling is a strategy used by many CNG early adopters to maintain reliably low fuel costs. It also speaks to the innovation of infrastructure providers that can now provide this benefit to smaller fleets. To support expected growth in the CNG market, new infrastructure will be required, with the expectation that a similar percentage of new private stations will be built (70%) compared to public access sites (30%).

NGVAMERICA

Natural Gas Vehicles for America

Industry Perspective: Natural Gas Vehicles America (NGVA)

With environmental sustainability at the top of the global agenda and companies around the world focusing on decarbonizing operations, natural gas and RNG vehicles deliver a clean fuel transportation solution that is cost effective and deployable today. Other favorable factors include significant price discount of natural gas relative to gasoline and diesel fuel, which in 2022 increased dramatically, and billions in new funding under the IIJA that will directly benefit transit agencies, clean school buses, alternative fuel infrastructure projects, cleaner trucks, and low carbon strategies, among other things.

Enabled by an expansive list of commercially available MD and HD options, natural gas freight trucks, refuse, transit, delivery, and work trucks continue to drive natural gas adoption. Vehicle options are designed to meet the daily performance and range needs of fleets while delivering significantly low emissions. Our Start Now. RNG is How! report released in April, available at https://ngvamerica.org/rng-is-how, details just how fleets can achieve sustainability goals and save money all while transitioning to natural gas vehicles fueled by RNG.

As was the case last year, the full-suite of HD Cummins natural gas engines continues to be available and all are certified to a near-zero emission 0.02 g/bhp-hr standard, 90% cleaner than the U.S. EPA's current NOx standard. And these ultra-low-NOx technologies available now meet the more stringent upcoming Clean Trucks Plan recently proposed by EPA. The additional benefit of refueling with RNG allows natural gas fleets to achieve carbon-negative emissions today.

In 2021, 64% of all natural gas used in on-road transportation nationally was RNG, up from 53% in 2020.[98] The average carbon intensity of bio-CNG sold in California continues to get better, dropping to -62.31 gCO2e/MJ in Q4 2021.[99] Based on the mix of fuel sold nationally, the average carbon intensity of all RNG is approximately 12.65 gCO2e/MJ.

RNG availability continues to grow. There are 250 production facilities in operation and more than 235 in the planning stages or under construction, and more states are looking to join California, Oregon, and Washington in adopting clean fuel standard programs.[100] 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.

Natural gas fleets of every size benefit from low, stable natural gas prices, allowing for a quick return on investment. Available government and local incentives can further reduce total cost of ownership. And expected multi-year extension of the federal $0.50/gallon AFTC and proposed $1/gallon Renewable Natural Gas motor fuel tax credit further encourage natural gas fleet adoption.

[98] Natural Gas Vehicles America, "Decarbonize Transportation with Renewable Natural Gas," May 2022, accessed at https://ngvamerica.org.

[99] California Air Resources Board, "LCFS Certified Carbon Intensities," downloaded 26 April 2022, accessed at https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities.

[100] Argonne National Laboratory, "Renewable Natural Gas Database," downloaded 26 April 2022, accessed at https://www.anl.gov/es/reference/renewable-natural-gas-database.

BATTERY-ELECTRIC VEHICLES

- Larger scale heavy-duty BEV projects are emerging and many of these fleets will go from a handful of units in 2021 to dozens and even hundreds in 2022 and 2023.
- Most startup BEV OEMs in the LD and MD BEV segment have experienced production delays, while large traditional OEMs are beginning to deliver BEV products to customers in very small numbers, with significant orders to be fulfilled in 2022 and beyond.
- Global OEMs continue to deliver on, and even accelerate, their investment commitments to BEVs with top OEMs vying for early leads and market share in the MD market.
- Vehicles, batteries, and infrastructure costs have not fallen as fast as expected. Ongoing LDV cost decreases for batteries, a critical driver of vehicle cost, are not yet translating to MD and HD batteries.
- New national commitments by a coalition of utilities and other private sector investors will lay the groundwork for national charging networks. However, most early adoption by fleets to date has relied on private charging, which is expected to dominate in the near-term.

THE FLEET TYPES LEADING BEV ADOPTION

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

MUNICIPAL | SHUTTLE | TRANSIT | DELIVERY | UTILITY | SCHOOL | CARGO | DRAYAGE

Estimated Medium- and Heavy-Duty Vehicles in Operation

LOW-THOUSANDS	HUNDREDS	DOZENS

MARKET SNAPSHOT

Tractor and Yard Truck Fleets Begin Operating HD BEVs at Larger Scale

Continued technological innovation and improvement, the success of demonstration projects implemented in 2021, and a very favorable funding environment provided the necessary encouragement for fleets to pursue larger orders for additional electric trucks during the year and continuing into early 2022.

Several demonstration projects planned for 2022 will feature commercially certified trucks to help prove that fleets can successfully manage 10, 50, and even 100 BEVs and their charging requirements.

NFI and Schneider successfully applied for funding to purchase a total of 100 Class 8 battery electric tractors, including 80 Freightliner eCascadias and 20 Volvo VNRs. Similarly, Performance Team, a Maersk company, increased its initial order of 16 Volvo VNR electric tractors by 110 in early 2022 and expects to have all units in operation across multiple facilities by early 2023.[101] It also announced a commitment to deploy 300 Einride electric trucks within its North American network between 2023 and 2025, with the first batch of these being BYD Class 8 8TT Gen 3 units.[102] Likewise, startup truck-as-a-service (TaaS) provider WattEV placed an order for 50 Volvo VNR electric trucks for its HD BEV charging infrastructure development plans in California.[103] Orange EV began filling second orders for yard trucks from Albertsons and discussing order volumes with Benore after successful testing; in early 2022, Orange EV was recognized for having the most Class 8 BEV yard trucks in operation nationwide.[104,105]

Several demonstration projects planned for 2022 will also feature commercially certified trucks in larger volume deployments to help prove that fleets can successfully manage 10, 50, and even 100 BEVs and their charging requirements. California's Zero Emission Drayage Truck and Infrastructure Pilot Project has some vehicle deliveries slated for 2022 and 2023, with at least 50 Class 8 BEVs from each of the following OEMs being used in drayage service: Freightliner (80), Lion Electric (50), Navistar (53), Tesla (50), and Volvo Trucks North America (VTNA) (70). This will be a significant test of vehicle charging infrastructure, including that of utilities to deliver sufficient and cost-effective power. These orders come just two years after Daimler Truck North America (DTNA) was the first major manufacturer to deliver an HD BEV to Penske Truck Leasing and NFI to demonstrate the real-world applications of the technology.[106]

Aside from the tractor and yard trucks segments, after successfully piloting a refuse truck from Mack in 2020, the New York City Department of Sanitation, the world's largest municipal sanitation department, ordered an additional seven battery-electric Mack refuse trucks, a substantial BEV order for the refuse sector.[107] Additional announcements for battery-electric refuse truck sales are anticipated in 2022.

Two MD Players Vie for Market Share

Competition for the MD fleet BEV market is increasing, with global OEMs Ford and GM both expanding their support services to fleets.

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[101] Volvo Trucks USA Newsroom, "Volvo Trucks Receives Largest Global Order for 110 VNR Electric Trucks from Performance Team – a Maersk Company," 29 March 2022, accessed at https://www.volvotrucks.us/news-and-stories/press-releases/2022/march/volvo-trucks-receives-largest-global-order-for-110-vnr-electric-trucks-from-a-maersk-company/.

[102] https://www.worktruckonline.com/10164277/performance-team-orders-300-einride-electric-trucks.

[103] Volvo Group Newsroom, "New York City Department of Sanitation to purchase seven Mack® LR Electric models," 30 June 2021, accessed at https://www.volvogroup.com/en/news-and-media/news/2021/jun/news-4013033.html.

[104] Fisher, Josh, "EV opportunities are blooming in terminal yards," FleetOwner, 6 April 2022, accessed at https://www.fleetowner.com/emissions-efficiency/article/21238247/ev-opportunities-are-blooming-in-terminal-yards-for-more-sustainable-fleets.

[105] Huff, Aaron, "CCJ Symposium: Fleets are clearing hurdles to reach zero emissions," CCJ, 20 August 2021, accessed at https://www.ccjdigital.com/ccj-symposiums/article/15114000/how-fleets-are-clearing-hurdles-to-reach-zero-emissions.

[106] Penske Newsroom, "Penske Truck Leasing Receives First Battery-Electric Truck from Daimler", 20 December 2018, https://www.gopenske.com/blog/lease/penske-truck-leasing-receives-first-battery-electric-truck-from-daimler.

[107] Volvo Group Newsroom, "New York City Department of Sanitation to purchase seven Mack® LR Electric models," 30 June 2021, accessed at https://www.volvogroup.com/en/news-and-media/news/2021/jun/news-4013033.html.

Upon announcing specs for the F150 Lightning, Ford revealed Ford+, the creation of a national network of 2,300 EV-certified dealerships and 644 commercial vehicle centers.[108] It now offers Ford Pro, a first-of-its kind service among OEMs, which includes a comprehensive suite of financing, charging, and dealership support for fleet operators to seamlessly integrate EVs into a traditional fleet.[109]

Reservations for Ford's F-150 Lightning exceeded 120,000, prompting the company to invest another $250 million to double its 2024 production target to 80,000 units and double it again in 2025.

Meanwhile, GM's BrightDrop opened its first dealerships last year and announced the launch of Ultium Charge 360, a service connecting fleets to EVSEs.[110] GM aims to incorporate more than 60,000 public charging facilities into its service through partnerships with eTransEnergy (Duke Energy), EVgo, IN-Charge Energy, and Schneider Electric.[111]

Ford and GM are accelerating production timelines to meet high demand. Reservations for Ford's F-150 Lightning exceeded 120,000 at the end of August, prompting the company to invest another $250 million to double its 2024 production target to 80,000 units and double it again in 2025.[112] Ford is increasing its investment in BEVs from $22 billion in February 2021, to $30 billion through 2025 and aims to achieve a 40% BEV share of total sales by 2030.[113,114]

Ford received orders for more than 10,000 of its electrified delivery van, the eTransit, from more than 300 customers, with Walmart requesting more than 1,100 vehicles and Penske Truck Leasing ordering 750 units.[115,116]

GM's BrightDrop moved from public reveal to customer production within a calendar year by delivering the first five EV600 Class 2 box vans to FedEx in December 2022. The initial five trucks were the first to fulfil an order of 500 from the parcel leader.[117] GM also accelerated its two-year plan, released January 2021, by announcing that it intended to stop production of the Chevrolet Equinox crossover by April 2022 in order to retool a plant in Ontario that will be used to produce BrightDrop's EV600 commercial van, beginning in November 2022.[118] BrightDrop also announced plans to produce an EV410 van with higher maneuverability than the EV600 scheduled for

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[108] Work Truck Staff, "Ford F-150 Lightning Pro Launched for Commercial Fleets," Heavy Duty Trucking, 24 May 2021, accessed at https://www.truckinginfo.com/10144074/ford-f-150-lightning-pro-launched-for-commercial-fleets.

[109] Ford Newsroom, "New 'Ford Pro' Vehicle Services and Distribution Business Redefining Transportation Value for Commercial Customers," downloaded 7 February 2022, accessed at https://media.ford.com/content/fordmedia/fna/us/en/media-kits/2021/ford-pro.html.

[110] Automotive News, "GM's BrightDrop opens first dealership", 7 December 2021, https://www.autonews.com/automakers-suppliers/gms-brightdrop-opens-first-dealership

[111] GM Corporate Newsroom, "BrightDrop and FedEx Take Part in Record-Setting EV Campaign," 22 April 2022, accessed at https://media.gm.com/media/us/en/gm/home.detail.html/content/Pages/news/us/en/2021/jul/0715-ultium.html.

[112] Edelstein, Stephen, "Ford F-150 Lightning production target reportedly doubles, as electric-truck anticipation builds," Green Car Reports, 25 August 2021, accessed at https://www.greencarreports.com/news/1133348_ford-f-150-lightning-production-target-doubles-electric-truck-anticipation.

[113] Wayland, Michael, "Ford ups EV investments, targets 40% electric car sales by 2030 under latest turnaround plan," CNBC, 26 May 2021, accessed at https://www.cnbc.com/2021/05/26/ford-ups-ev-investments-targets-40percent-electric-car-sales-by-2030-under-latest-turnaround-plan.html.

[114] Gilboy, James, "Ford Invests Extra $250M Into F-150 Lightning Production to Satisfy Demand," The Drive, 16 September 2021, accessed at https://www.thedrive.com/news/42407/ford-invests-extra-250m-into-f-150-lightning-production-to-satisfydemand.

[115] Mihalascu, Dan, "Ford E-Transit Hits 10,000 US Orders, including 1,100 From Walmart," Inside EVs, 26 January 2022, accessed at https://insideevs.com/news/563265/ford-etransit-10000-orders-usa/.

[116] Grzelewski, Jordyn, "Penske Truck Leasing orders 750 all-electric E-Transit vans from Ford," 18 April 2022, The Detroit News, accessed at https://www.detroitnews.com/story/business/autos/ford/2022/04/18/penske-truck-leasing-orders-750-all-electric-e-transit-vans-ford/7359952001/.

[117] FedEx Newsroom, "Charging Ahead: FedEx Receives First All-Electric, Zero-Tailpipe Emissions Delivery Vehicles from BrightDrop," 17 December 2021, accessed at https://newsroom.fedex.com/newsroom/brightdropev600/.

[118] The Canadian Press Staff, "GM to stop making Equinox at Canadian plant in April, will switch to electric vehicles," Global News, 30 June 2021, accessed at https://globalnews.ca/news/7992480/general-motors-chevy-equinox-electric-vehicles-cami-ingersoll/.

> **"Purchasing and utilizing EVs has greatly surpassed our expectations as it relates to the speed, performance, charging, and maintenance costs. The vehicles are fun to drive, and our user departments are satisfied."**
>
> — Cathy Crum, Contract Manager, City of Tallahassee, Florida

production in 2023, along with a reservation from Merchants Fleet for 5,400 units.[119]

Big moves by leading MD OEMs come following the partnerships announced by Amazon with startup Rivian for a commitment of 100,0000 delivery vans and UPS with startup Arrival for 10,000 vehicles that were reported in previous editions of State of Sustainable Fleets.

School Bus Market Sees Early Performance Results, Increased Orders

The battery-electric school bus market experienced a substantial rebound in 2021 with a total of 612 units purchased, up from just 20 purchased in 2020. To date, more than 350 fleets have ordered or deployed approximately 1,800 electric school buses in the U.S., with the majority of these being Type C and D models from Thomas Built, Blue Bird, and Lion Electric.[120] Although the geographic focus of the State of Sustainable Fleets report is the U.S., it is notable that Canadian division of U.S.-based Student Transportation of America placed a conditional order for 1,000 electric school buses in October 2021.[121]

Regulatory and funding developments are expected to continue to create demand for battery-electric school buses. The State of New York passed a budget with a rule that will require the estimated 50,000 school buses in the state to transition to zero-emission by 2035, with purchases beginning as early as 2027.[122] The IIJA sets aside half of the $1 billion annually for the next five years for zero-emission school bus technologies. Some early adopters of electric school buses are already seeing improvements in TCO. Twin Rivers School District in Northern California currently runs 40 battery-electric school buses and has reported an 80% reduction in fuel costs, with further revenue generation being realized via LCFS credits. Maintenance costs have dropped 70%, and the district reports practically zero cost for inventory, as well as extended brake and tire life. With much of the costs covered by the more than $29 million the district has received in grants. It is also planning to install 22 new chargers to be vehicle-to-grid (V2G) compatible. V2G could provide additional financial benefit to the district through payment from the utility for access to the battery during vehicle down times.

> **To date, more than 350 fleets have ordered or deployed approximately 1,800 electric school buses in the U.S.**

[119] FleetOwner, "Merchants Fleet accelerates electrification with purchase of 5,400 BrightDrop EV410s," 23 November 2021, accessed at https://www.fleetowner.com/emissions-efficiency/electric-vehicles/article/21181967/merchants-fleets-accelerates-electrification-with-purchase-of-5400-brightdrop-ev410s.

[120] World Resources Institute, "Dataset of Electric School Bus Adoption in the United States," 16 December 2021, accessed at https://datasets.wri.org/dataset/electric_school_bus_adoption.

[121] Student Transportation of America, "Student Transportation of America Exploring the Deployment of Zero-Emission School Buses in Canada," PR Newswire, 25 October 2021, accessed at https://www.prnewswire.com/news-releases/student-transportation-of-america-exploring-the-deployment-of-zero-emission-school-buses-in-canada-301406959.html.

[122] Lewis, Michelle, "New York State commits to 100% electric school buses by 2035," 8 April 2022, accessed at, https://www.wkbw.com/news/local-news/nys-budget-all-state-school-buses-must-be-zero-emission-by-2035.

> **"We currently have 55 EV school buses and will have the infrastructure to support 83 EV buses by Q3 2022 and at that time should be deploying 78 buses from this upgrade."**
>
> — Linda Lemon, Administrative Secretary, Twin Rivers School District, California

Of all the segments covered, the school bus market appears to be furthest along in terms of offering V2G compatible BEVs. However, few projects have yet to demonstrate the technology due to the significant number of regulatory, technical, and other hurdles that have yet to be addressed within the market and electric utility systems. V2G capable school buses are being offered by Blue Bird, Lion Electric, and Thomas Built Buses.[123,124]

Given the need for school districts to take advantage of funding programs to procure battery-electric buses, several new federal programs will provide an important stimulus to the forward growth of this market in the years to come. Under the 2021 American Rescue Plan, an additional $7 million was provided to the U.S. EPA's Diesel Emissions Reduction Act (DERA) Program to increase the funding for each electric school bus from $65,000 to $300,000 per bus. Under the IIJA, $5 billion was allocated to provide $500 million for battery-electric school buses and $500 million for ZE or NZE school bus funding in each of the next five years.

An interesting trend observed in the last year is a movement to repower existing school buses with battery-electric drivetrains, with the goals being a shorter timeline to get electric buses on the road (which can be weeks versus months), lower costs for the electric bus (by approximately 50%), and a more favorable opportunity for a positive TCO. SEA Electric and Midwest Transit Equipment also announced an agreement to repower 10,000 school buses to battery electric during the next five years.[125]

Commitments to Expand National Charging Infrastructure Grows

A majority of MD and HD BEV charging now takes place on-site within a fleet yard, which is consistent with the data and trends for other more mature fuels like propane and natural gas. Given the incremental level of investment in the BEV market by the public and private sectors, and the increased regulatory focus on forcing BEV sales and deployments, public charging infrastructure will likely be more important in the years ahead. With the anticipated growth of the commercial BEV market in the next five years and beyond, there is growing focus on the development of public access charging infrastructure, networks, and corridors.

> **V2G capable school buses are being offered by**
>
> **Blue Bird, Lion Electric, and Thomas Built Buses.**

In late 2021, a consortium of 51 investor-owned utilities led by industry group Edison Electric Institute (EEI) formed the National Electric Highway Coalition.[126] EEI estimates that more than 100,000 EV fast charging ports will be needed to

[123] Doll, Scooter, "Cummins claims to power first vehicle-to-grid school buses in North America, 2 years after Lion," Electrek, 25 March 2021, accessed at https://electrek.co/2021/03/25/cummins-to-power-first-vehicle-to-grid-school-buses-in-north-america/.

[124] Thomas Built Buses Newsroom, "Why electric school buses? Because tomorrow has never been more important.," downloaded 7 February 2022, accessed at https://thomasbuiltbuses.com/electric-school-buses/electric-bus/.

[125] Lewis, Michelle, "10,000 North American school buses will be converted to fully electric," Electrek, 7 December 2021, accessed at https://electrek.co/2021/12/07/10000-north-american-school-buses-will-be-converted-to-fully-electric/.

[126] Green Car Congress, "Electric companies form National Electric Highway Coalition to develop national fast-charging network", 15 December 2021, https://www.greencarcongress.com/2021/12/20211215-nehc.html.

support the projected 22 million EVs (including passenger vehicles) that will be on U.S. roads by 2030. The goal of the coalition is to develop fast charging along major U.S. travel corridors to fill infrastructure gaps by 2023, though the details have not yet emerged around how tailored to or accessible these will be for the needs of fleet operators.

BlackRock Renewable Power, along with NextEra Energy Resources and DTNA, signed a memorandum of understanding (MOU) in early 2022 to develop a joint venture to design, develop, install, and operate a nationwide, high-performance charging network for MD and HD battery-electric and hydrogen FCEVs in the U.S. Initial funding for the project was forecasted to be $650 million. By 2026, the plan is to build networks on critical freight routes on the East and West Coasts, as well as in Texas, using existing infrastructure sites and developing new ones, with hydrogen infrastructure being developed later. Infrastructure developer Electrify America also announced an investment of up to $35 million in transit, MD, and HD fleet charging in California during the next two years.[127]

WattEV announced that it was building a public network of HD battery-electric truck charging depots to service major transportation corridors, connecting shipping ports with freight distribution centers and warehouse locations within California. As WattEV's public charging network expands nationwide, the company plans to scale its depots to provide 1.2 MW charging capability for ultra-fast charging concurrent with availability of trucks from OEMs that support the upcoming megawatt charging system (MCS) standard, a charging connector under development for HD BEVs.

BlackRock Renewable Power, NextEra Energy Resources and DTNA, signed an MOU in 2022 to develop, install, and operate a nationwide, high-performance charging network for MD and HD battery-electric and hydrogen FCEVs in the U.S.

Models are Offered, But Not All Are Currently Available as Supply Ramps Up

Fleets looking to deploy BEVs have more advertised choices today than ever before, but not all are ready for delivery (Figure 7). During the past year, more than 170 BEV models have been advertised by OEMs and aftermarket providers, with only 70% available for customer order. While many of the aftermarket and startup BEV manufacturers were quick to market with announcements and prototypes, getting to commercial production and scale has been a challenge.

Compared to the prior year, model availability grew in the HD tractor segment by 60% from five models to eight, HD straight truck by 25% from three models to five and refuse by 200% from two models to six. Unfortunately, fleets have found that the MD and HD BEV markets have been affected by delivery delays, with Tesla's Semi tractor being the most notable example where delivery of the first units has been delayed

During the past year, more than 170 BEV models have been advertised by OEMs and aftermarket providers, with only 70% available for customer order.

[127] Electrify America Newsroom, "Our Investment Plan," downloaded 7 February 2022, accessed at https://www.electrifyamerica.com/our-plan/.

from 2019 to at least 2023. Delays have been particularly significant in the MD market segment due to the high ratio of new entrants taking orders before fully building and scaling their production facilities. New entrants also have less established supplier relationships and have therefore been more susceptible to supply chain shortages. For example, Rivian, Lightning eMotors, and Nikola are among the manufacturers that have cut 2022 investments and production targets due to expected ongoing supplier delays.[128,129] Meanwhile, established manufacturers such as Ford, GM, DTNA, VTNA, Peterbilt, International, and others have been working to develop their production capabilities and ramp up marketing and sales efforts.

Despite some delays, there has also been considerable progress. Currently, 14 battery-electric tractor models are either being produced or are in development. The cargo van segment has seen especially strong growth in the last two years, with 18 models either available or advertised from at least 14 manufacturers.

MD vehicles comprise 54% of the BEVs advertised as available today and 66% of MD BEVs are from aftermarket providers. In the popular and versatile MD stripped chassis, cargo van, chassis cab and cutaway segments, at least 80% of available models are from aftermarket providers, many of which advertise production status but have only filled low volume orders, if any at all. Global supply chain issues and the challenges of building new manufacturing plants and new vehicle platforms from the ground up — while in the middle of a global pandemic — have only contributed to these delays.

Forward scaling of MD BEV deliveries is expected in the years to come, especially from traditional OEMs, but also from the new BEV manufacturers once their supply chain and production issues are resolved.

"We will replace vehicles that have and/or approaching the end of their useful life with equivalent battery-electric vehicles as they become available."

— Robert Comitalo, Fleet Maintenance Supervisor, City of Philadelphia Department of Fleet Services, Pennsylvania

"The greatest challenge we face in transitioning to EVs is finding suitable models that meet specialized operations of our fleet. The second barrier is investing in charging infrastructure that is dependable on an inconsistent powergrid."

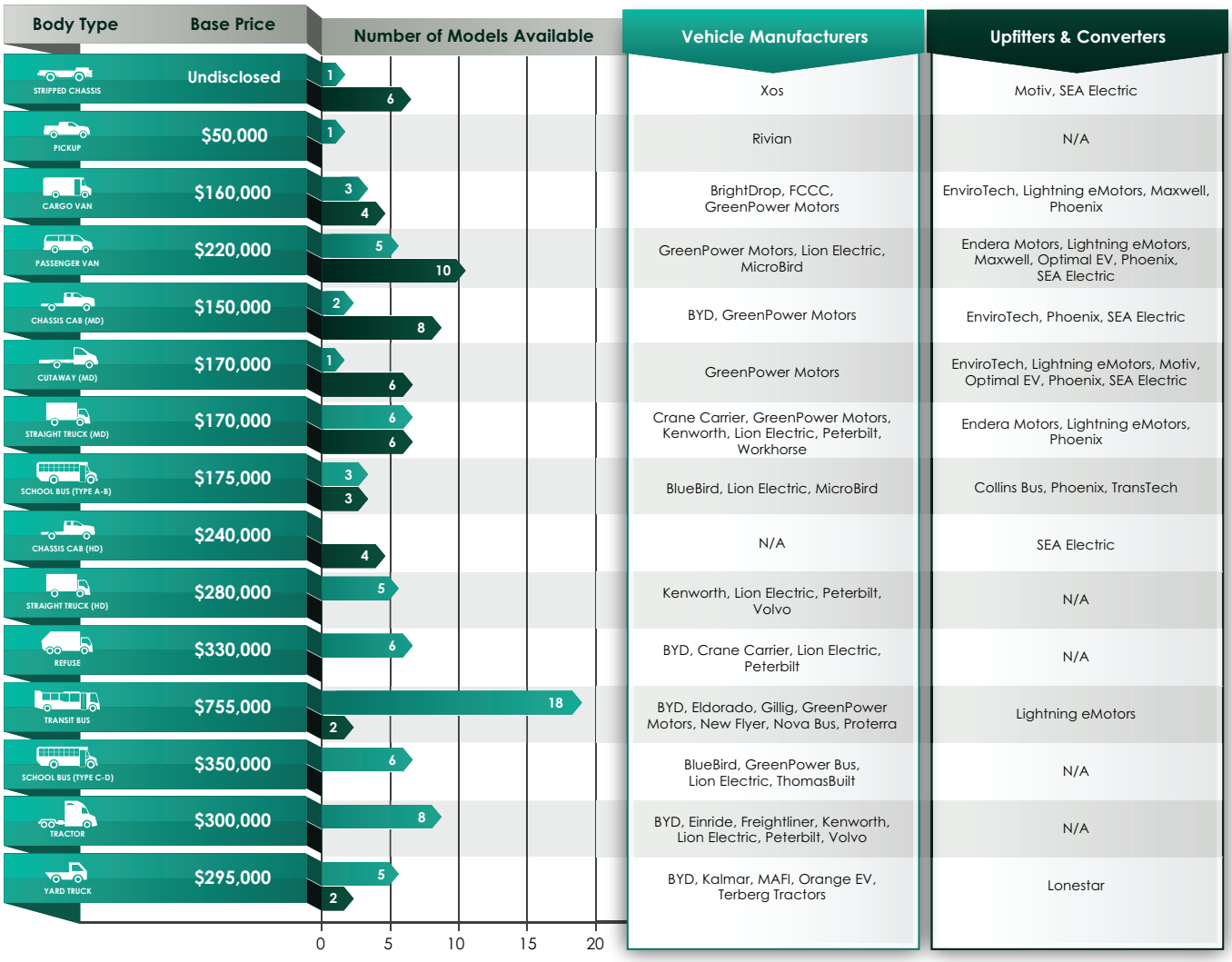
— Gavin Siegert, Sustainable Transportation Specialist, County of Alameda, California

[128] Lombaerde, Geert De, "Supply chain pain leads Rivian to slash 2022 target," FleetOwner, 14 March 2022, accessed at https://www.fleetowner.com/emissions-efficiency/electric-vehicles/article/21235897/supply-chain-pain-leads-rivian-to-slash-2022-target.

[129] Lombaerde, Geert De, "Lightning eMotors sees supply chain slowing growth 'for the next few quarters'," FleetOwner, 20 March 2022, accessed at https://www.fleetowner.com/emissions-efficiency/electric-vehicles/article/21237611/lightning-emotors-sees-supply-chain-slowing-growth-for-the-next-few-quarters.

THE BATTERY-ELECTRIC VEHICLE MARKET

MD and HD Battery-Electric Vehicles (Limited to Full Production)



MD and HD Battery-Electric Vehicles (Announced to Active Demonstration)

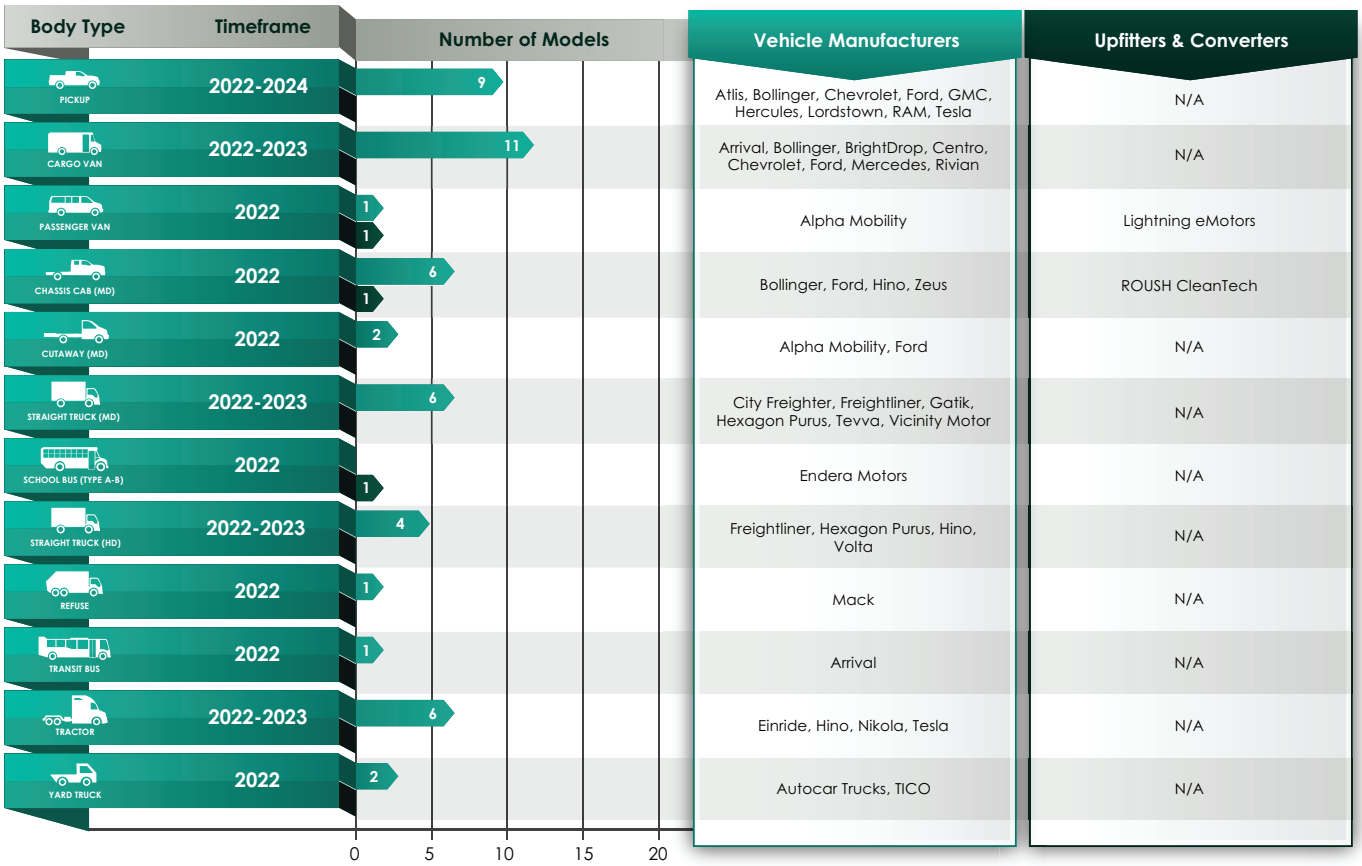


Figure 7: BEVs offered by OEMs, upfitters, or converters producing new-build vehicles.

Battery and Charging Infrastructure Costs Remain Stubbornly High

With many BEVs still in limited production, there have been no major price decreases observed for any one vehicle type. Prices for batteries, a critical driver of end-vehicle cost, remain stubbornly high. While LD vehicle battery pack prices dropped to approximately $140/kWh in 2021, HD vehicle battery pack costs are still at least double the price of their LD counterparts due to currently low production volumes. Market analysts suggest that prices could even rise in the short term from 2021 due to mineral shortages and supply chain disruptions.[130] While 13 new EV battery production plants in the U.S. are expected to be operational by 2025, only two currently plan to produce batteries for the commercial vehicle market.[131,132] The combined lower volume market of the MD and HD segment compared to passenger cars, the larger battery pack requirements for HD vehicles, and other scaling considerations suggest that the cost/kWh curve for the commercial sector may follow a different trajectory than the LD sector.

Looking beyond current low volume market pricing, most predict that battery and delivered BEV costs will decrease in the coming decade.

[130] Sharpe, Ben and Hussein Basma, "A meta-study of purchase costs for zero-emission trucks," February 2022, International Council on Clean Transportation.

[131] Adler, Alan, "Electric truck charging: Can infrastructure keep pace with demand?," Freight Waves, 4 January 2022, accessed at https://www.freightwaves.com/news/electric-truck-charging-can-infrastructure-keep-pace-with-demand.

[132] Vehicle Technologies Office, "FOTW #1217, December 20, 2021: Thirteen New Electric Vehicle Battery Plants Are Planned in the U.S. Within the Next Five Years," U.S. Department of Energy, 20 December 2021, accessed at https://www.energy.gov/eere/vehicles/articles/fotw-1217-december-20-2021-thirteen-new-electric-vehicle-battery-plants-are.

Many experts project that Class 8 battery costs are expected to be cut in half to $100 per kWh, and component costs — motors, inverters, transmissions, etc. — should decline by almost 80% by 2030.[133] Such predicted cost reductions would be consistent with forecasts out of the U.S. and Europe that have indicated that Class 8 tractor base prices may decline by as much as 50% by 2030.[134]

> **"Drivers liked the BEVs we piloted in 2021, but infrastructure is a larger hurdle than most people realize."**
>
> — Tommy Cottingham, Senior Director of Maintenance and Equipment Procurement, J.B. Hunt Transport, Arkansas

Costs within the charging infrastructure market may be in a similar holding pattern. According to recent grant-funded projects and purchase experiences by several fleets from the past year, no significant cost reductions were observed in the EVSE market in 2021.[135] Just as in the automotive industry, inflation and supply chain constraints impacted the market. Fleets also reported that soft costs related to current demonstrations and large-scale installations of EVSE continue to be major components of the total project cost. Labor for installation of a DCFC can be as much as the equipment itself, and total "soft" costs — design, permitting, commissioning, weatherizing, networking and cable management — can add up to as much as 60% of the total project cost.[136]

OEMs Expand Beyond Manufacturing to Support Fleets

A noticeable trend in the last year has been the expansion of the traditional role of OEMs as vehicle manufacturers into a much more comprehensive customer engagement and project facilitation role. Due to the complexity of BEV development projects, OEMs have found themselves taking a much more hands-on role with end-use customers. OEMs are increasingly helping customers assess how BEVs will perform in their operations and duty cycles, while also identifying potential constraints and the best routes for the technology. In terms of fleet planning, OEMs are engaging with customers early on, discussing how BEVs will perform in a fleet's existing conditions and constraints. Last spring, DTNA launched Detroit eConsulting, which provides customers with a team of e-mobility experts to help fleets navigate electric truck conversion projects. Lightning eMotors offers grant and incentive assistance for fleets, as well as driver and maintenance training.

Beyond a focus on the vehicles and fleet operations, OEMs are even branching out into the development of BEV charging infrastructure. GM, VTNA, Ford, DTNA, and Nikola have all either launched partnerships with EVSE providers or are developing their own branded EVSE and software services to grow charging networks for LD, MD, and HD BEVs. Taking this even one step further, some OEMs also offer assistance with power procurement, including cleaner-than-grid options. Navistar offers clean power procurement through the purchase of renewable energy credits.[137]

> **"We are working to pilot Class 8 EVs and have realized this transition requires close collaboration with multiple parties to overcome challenges like lead-times, availability, and required infrastructure."**
>
> — Ted Valin, Senior Director Asset Management, DHL Supply Chain, Ohio

[133] Sharpe, Ben and Hussein Basma, "A meta-study of purchase costs for zero-emission trucks," February 2022, International Council on Clean Transportation.

[134] Ibid.

[135] GNA assessment of quotes in grant funded MD and HD BEV projects as well as market intelligence from leading fleets.

[136] GNA, California Fleet Electrification Case Study, 2021. Prepared for Environmental Defense Fund, page 28.

[137] Bus & Motorcoach News, "New Flyer expands electric bus battery recycling partnership," 12 November 2021, accessed at https://www.busandmotorcoachnews.com/new-flyer-expands-electric-bus-battery-recycling/#:~:text=Li%2DCycle%20can%20now%20provide,for%20heavy%2Dduty%20battery%20recycling.

As projects are further developed, OEMs are supporting fleets by connecting them with innovative new financing options. For example, Daimler Truck Financial Services offers tailor-made solutions for ZEV trucks and buses that include finance offerings that support acquisition of chargers and VTNA's Electric Vehicle Financial Services offers similar financing tailored to BEVs and infrastructure. Lion Electric also launched LionCapital Solutions, a new division within the company that offers financing solutions specifically tailored to the MD and HD BEV market.

These early market development efforts by vehicle OEMs are noteworthy, as they are a departure from the traditional model where OEMs manufacturer vehicles, and sales, service and support functions are handled by a dealer network. As the BEV market matures and grows, the ability for centralized OEMs to support wide customer engagement will become increasingly limited. In 2021, several of the large OEMs began to train select dealerships on their BEV products so these dealers can fill these traditional sales, support, and service roles with the customer.

OEMs Form New Partnerships for Battery Recycling

For all the known environmental benefits of BEVs' ability to eliminate tailpipe emissions, there is growing concern about the environmental impacts that result from the disposal of the battery at the end of its useful life. Typical warranties for batteries range from five to 10 years and are designed to cover batteries until their capacity degrades more than 20%. When the battery is out of warranty, there is no current standard for handling or disposal.

> **"The planning, costs and bidding out of work for installation of electrical infrastructure will continue to cause issues in locations that do not have enough existing infrastructure."**
>
> — Tony Cademarti, Fleet Program Manager, City of Everett Motor Vehicle Division, Washington

While end-of-life battery treatment faces several challenges, solutions exist, and companies are starting to prove-out their concepts. The Volvo LIGHTS project studied the possibility of using second-life batteries to improve grid and facility resiliency as well as to provide load management.

In the transit and motorcoach segment, Canadian bus manufacturer NFI Group now offers customers access to battery recycling through Li-Cycle, under a formal program announced late in 2021 that followed a year-long proof of concept.[138,139] Li-Cycle's process recovers resources from lithium-ion batteries at the end of their useful life for use of those materials in other products. GM's Ultium Cells LLC, a battery production joint venture with LG Energy Solutions, also partnered with Li-Cycle on recycling scrap metal from Ultium's battery manufacturing processes, reducing landfill waste and the demand for raw materials.[140] Ford has partnered with battery recycling startup Redwood Materials to incorporate battery recycling into the OEM's domestic battery strategy.[141] The partnership aims to improve the reliability of domestically sourced battery materials for Ford's BEV production targets.

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[138] Sustainable Bus Newsroom, "New Flyer electric bus batteries recycled with Li-Cycle. A first pilot," 11 January 2021, accessed at https://www.sustainable-bus.com/news/new-flyer-li-cycle-electric-bus-battery-recycling/.

[139] GM Corporate Newsroom, "Ultium Cells LLC and Li-Cycle Collaborate to Expand Recycling in North America," 11 May 2021, accessed at https://plants.gm.com/media/us/en/gm/home.detail.html/content/Pages/news/us/en/2021/may/0511-ultium.html.

[140] Grzelewski, Jordyn, "Ford partners with, invests $50M in Rivian rival Tesla co-founder's battery recycling startup," The Pantagraph, 23 September 2021, accessed at https://pantagraph.com/business/ford-partners-with-invests-50m-in-rivian-rival-tesla-co-founders-battery-recycling-startup/article_26fc07bf-d5d5-5862-b0ee-885cf0f5395e.html.

[141] IEA, "Renewables 2021," downloaded 7 February 2022, accessed at https://iea.blob.core.windows.net/assets/5ae32253-7409-4f9a-a91d-1493ffb9777a/Renewables2021-Analysisandforecastto2026.pdf.

Renewable Electricity Advances Nationally

In 2021, the IEA forecasted that U.S. renewable capacity on the grid would expand by 65% by 2026, adding 200 GW by solar (75%) with the remainder mostly wind.[142] The sector faces similar policy, cost, and infrastructure barriers as the EV infrastructure and vehicle sectors, with a need for increased and robust transmission and distribution infrastructure to deliver the expected renewable power to the places it is required.

Programs such as California's LCFS program require fuel producers and encourage transportation stakeholders to reduce the carbon content of their fuel consumption. In 2021, fleet consumption of lower-than-grid-average CI in California more than doubled, comprising the majority of electricity consumption by on-road MD and HD vehicles. Total electricity consumption increased 24% in the first three quarters of 2021 compared to the previous year.[143] In many cases, low-CI electricity on California's LCFS was achieved through the purchase of renewable energy credits (RECs) rather than the direct consumption of renewable power.

In the annual fleet survey, 38% of fleets that have operated BEVs say they have installed on-site renewable electricity.

As larger HD BEV projects are now in the development stage, fleets have increasingly been looking to leverage on-site solar power generation paired with battery storage systems to both increase the use of renewable energy as a truck fuel and address resiliency concerns. In the annual fleet survey, 38% of fleets that have operated BEVs say they have installed on-site renewable electricity. Several of the large, grant-funded projects with large fleet deployments of Class 8 BEVs above included on-site renewable electricity, in addition to others like one funded by the California Energy Commission for Sysco Corporation to test on-site solar and storage to support 40 battery-electric tractors at its Riverside, California, location.

"We have been excited on the path we chose a year ago to integrate microgrids powered by renewable energy to help reduce our carbon footprint and to be better partners to our customers, employees, and the communities we operate in."

— Taki Darakos, Director of Maintenance, Pitt Ohio, Pennsylvania

Fleets choose to use RECs or on-site renewable electricity for different project types and goals. Projects without on-site electricity generation in California benefit from a financial gain for purchasing RECs. Fleets aiming to maximize their TCO and reduce overall costs may be the ones using this strategy and avoid the additional capital cost of installing on-site solar.

Standardization Moves to Address Several Critical Needs

Electric vehicle stakeholders are collectively addressing the need for a charging standard to support 1 MW or higher charge rates for Class 6-8 vehicles.[144] As HD BEV demonstrations advance, fleets are more clearly defining the battery capacity that they require to complete their routes, as well as the timeframe that they consider reasonable to charge vehicles between shifts.

[142] IEA, "Renewables 2021," downloaded 7 February 2022, accessed at https://iea.blob.core.windows.net/assets/5ae32253-7409-4f9a-a91d-1493ffb9777a/Renewables2021-Analysisandforecastto2026.pdf.

[143] California Air Resources Board, "Low Carbon Fuel Standard Quarterly Summary," 31 January 2022, accessed at https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries.

[144] Charln, "Megawatt Charging System (MCS)," downloaded 7 February 2022, accessed at https://www.charin.global/technology/mcs/.

The MCS went through iterative testing and validation with the National Renewable Energy Laboratory in 2021.[145] The system is being designed to be compatible with existing Combined Charging System (CCS) infrastructure, while supporting bi-directional power flow. Several HD BEV demonstrations are currently incorporating charging rates at this level. Commercial truck manufacturer Kenworth was awarded funding to demonstrate a 1 MW system on its T680 BEV on a route between Seattle and Portland.[146] Megawatt-level charging is part of the plan for DTNA and Portland General Electric's Electric Island, which opened in April 2021 near DTNA headquarters. WattEV aims to provide power at this level as well at its first MD/HD BEV charging hub project near Bakersfield, California.[147]

The timeline is unclear as to when an industry ready MCS standard will be commercially available and ready for use by commercial fleets. It is expected that the MCS standard will be approved sometime in 2022, at which point commercial hardware can begin to be developed, installed, and tested. Commercialization of the MCS will be an important industry topic to monitor in the years ahead, as it will enable longer routes and new applications to the HD BEV market.

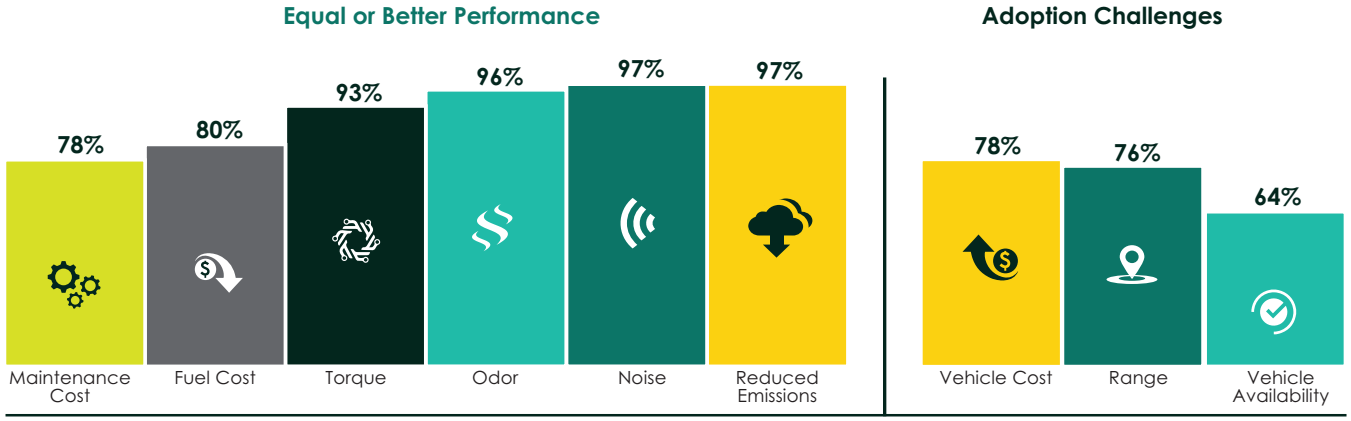
In the next 12 months, nearly all fleets (89%) that have already piloted or purchased BEVs expect to continue to invest in BEVs.

Fleet Adoption and Insights: BEVs

While it remains an emerging or early commercial technology among fleets that took the annual survey, more than half (52%) have either piloted or purchased at least one Class 2-8 BEV in the past two years. Public sector/government fleets lead adoption with 56% of government fleets in the annual survey, having piloted or purchased a MD or HD BEV since 2020, followed by 44% of private sector fleets.

PERFORMANCE AND ADOPTION RESULTS REPORTED BY BEV USERS

Percent of BEV users surveyed who cite a criteria as equal/better or an adoption challenge compared to diesel and gasoline.



Source: Percent of surveyed early adopter fleets that have either piloted or purchased MD or HD BEVs who cite a criteria as either equal/better or a challenge from the State of Sustainable Fleets 2022 survey.

Figure 8: Performance and adoption results reported by BEV users in the annual fleet survey.

[146] Kenworth Newsroom, "DOE Electrified Powertrain Project to Feature Kenworth T680 Next Gen Battery Electric Vehicle," 30 August 2021, accessed at https://kenworth.com/about-us/news/doe-electrified-powertrain-project-to-feature-kenworth-t680-next-gen-battery-electric-vehicle/.

[147] Adler, Alan, "Electric truck charging: Can infrastructure keep pace with demand?," Freight Waves, 4 January 2022, accessed at https://www.freightwaves.com/news/electric-truck-charging-can-infrastructure-keep-pace-with-demand.

Nearly all fleets that have either piloted or purchased BEVs report equal or better performance on emissions (97%), noise (97%), and odor (96%) (Figure 8). Additional operational strengths include torque (93%) and driver safety (88%), which fleets viewed as equal or better than their diesel counterparts. Not surprisingly, given that well-managed BEVs are expected to offer these benefits, fleets that have piloted or purchased BEVs in the annual survey report that fuel (70%) and maintenance costs (63%) stand out as benefits when compared to gasoline or diesel vehicles. Mirroring the biggest challenges to adoption cited by last year's fleet survey, early BEV adopters again cite vehicle cost (78%), range (76%), and availability (64%) as the top challenges of BEVs in this year's survey.

Private charging is becoming standard practice among fleets that are piloting or purchasing MD or HD BEVs, with 97% purchasing their own chargers. Many of these same fleets are pairing this with on-site energy storage (31%). Some are also integrating diesel or natural gas generators (18%) into their on-site energy generation.

In the next 12 months, many fleets in this year's survey plan to pilot or purchase MD or HD BEVs (67%), with nearly all fleets (89%) that have already piloted or purchased BEVs expecting to continue to invest in BEVs. These same fleets intend to purchase private charging (98%) in the next 12 months, and 35% of those fleets also intend to procure renewable electricity.

Edison Electric INSTITUTE

Industry Perspective: Edison Electric Institute (EEI)

Fleet electrification is a growing priority for policymakers and for commercial and public fleet operators, and it represents an important step toward meeting sustainability goals. In 2021, 40% of the nation's electricity came from clean, carbon-free sources like nuclear, hydropower, wind, and solar energy. Electric power sector carbon emissions have been declining for the last decade and are now 14% below transportation sector emissions. As the nation's energy grid becomes cleaner, the carbon and emissions reductions benefits of BEVs continue to increase.

On the policy front, the enactment of the IIJA in November 2021 was a watershed moment for the EV ecosystem, making more than $21 billion of federal funding available for electric transit buses, electric school buses, public EV charging infrastructure, and other areas over the next several years. In addition, new proposed standards for MD and HD vehicles from the U.S. EPA, as well as the growing number of states enacting or considering the ACT rule that requires manufacturers to sell an increasing share of zero-emission vehicle technology, will make 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 $3.4 billion in customer programs to support charging infrastructure and other actions to accelerate electric transportation. Nearly half of this investment is available for charging needs other than passenger vehicles, including fleet applications like school buses, transit buses, and others. These programs typically help to reduce the customer cost of installing charging infrastructure by providing rebates, providing "make-ready" infrastructure for customers, and/or providing end-to-end charging solutions. Fleet customers can find more information on these programs in EEI's EV Program Database, available at https://www.eei.org/issues-and-policy/electric-transportation/EVPrograms.

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.[148] While initially focused on providing confidence for individual EV drivers, LD 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 like that between DTNA and NextEra Energy Resources are laying the groundwork for dedicated MD and HD EV charging infrastructure.

In short, electric companies are preparing for a growing wave of fleet electrification and are eager to partner with both corporate and public fleet customers to ensure a seamless transition.

[148] Edison Electric Institute, "National Electric Highway Coalition," accessed at, https://www.eei.org/issues-and-policy/national-electric-highway-coalition.

HYDROGEN FUEL CELL ELECTRIC VEHICLES

- While no commercial FCEVs were delivered to fleet customers in 2021, vehicle orders quadrupled across the transit and HD tractor segments, and the largest demonstrations and orders for Class 8 FCEV trucks in the U.S. to date were initiated.
- Transit continues to lead FCEV adoption by vehicle count, but dozens of tractors were awarded grant-funding and are expected to be on order soon.
- California transit agencies that are required to transition to ZEVs are planning for FCEVs in higher numbers than predicted.
- No public hydrogen stations were opened outside of California in 2021, but private investments are expected to launch infrastructure along key transportation corridors.
- At least 110 stations for LD and MD vehicles and 16 stations for HD vehicles are planned to be developed in California, Ohio, New York, Rhode Island, Connecticut, and Massachusetts in the coming years.

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 (DOZENS) | DEMONSTRATION (ABOUT A DOZEN)

MARKET SNAPSHOT

After a COVID-19 Pause, Hydrogen Development Resumes

While COVID-19 delays impacted hydrogen station development in 2020, this past year signaled a rebound in hydrogen infrastructure planning, although many projects are still in their early stages of development.

Public and private funding of future hydrogen fueling stations and production facilities, as well as promising partnerships, continue to lay a strong foundation for this emerging clean fuel and build on the potential of fuel cell technology. After a COVID-19 Pause, Hydrogen Development Resumes

While COVID-19 delays impacted hydrogen station development in 2020, this past year signaled a rebound in hydrogen infrastructure planning, although many projects are still in their early stages of development. Public and private funding of future hydrogen fueling stations and production facilities, as well as promising partnerships, continue to lay a strong foundation for this emerging clean fuel and build on the potential of fuel cell technology.

Commercialization of fuel cell technology for the HD fleet segment remains on track. Total U.S. commercial HD FCEV purchases in 2021 were just shy of 150 — four times the number of purchases recorded in 2020. Indicators of increased adoption rates in the transit sector and first deliveries of Class 8 tractors for fleet demonstration show strong interest in developing the technology as an HD solution. Continued public and private investments along with new and expanded fueling partnerships could signal a FCEV future that's closer than most fleets think, although significant challenges remain before a cost-competitive future is fully realized.

Purchases of HD FCEVs increased four-fold in 2021, to 143 transit buses, all for New Flyer's commercial HD bus, and several tractors.

Transit Leads Adoption, Indicates FCEVs May Fit Sector Better Than BEVs

Purchases of HD FCEVs increased four-fold in 2021, to 143 transit buses. All transit bus purchases were for New Flyer's commercial HD bus, and tractor orders were spread across several manufacturers. For many transit agencies, FCEVs address concerns over limited vehicle range, per-vehicle fueling infrastructure costs, fueling times, and smaller infrastructure footprints compared to other technologies. Hydrogen maintains many of the same operational and fueling characteristics to natural gas, which many transit agencies have previously tested and adopted at scale. According to this year's survey of fleets that have piloted or purchased clean fuels or technologies, one-quarter of fleets that have piloted FCEVs are transit operators.

A recent analysis of large transit agency rollout plans developed in compliance with the regulation indicates that 18% of the state's large agency fleet may be powered by hydrogen, a big jump from the 1% assumed by CARB when the ICT rule was passed.

In California, fuel cell electric bus adoption among transit agencies is forecasted to be higher than originally anticipated. The state's Innovative Clean Transit (ICT) regulation requires public transit agencies to transition 100% of their fleets to ZEVs by 2040, with tiered ZE purchase requirements beginning in 2023 for large transit agencies and 2026 for small transit agencies.[149,150] A recent analysis

[149] EGNA analysis of ICT Roadmaps.

[150] California Air Resources Board, "Innovative Clean Transit (ICT) Regulation Fact Sheet," downloaded 7 February 2022, accessed at https://ww2.arb.ca.gov/resources/fact-sheets/innovative-clean-transit-ict-regulation-fact-sheet.

of large transit agency rollout plans developed in compliance with the regulation indicates that 18% of the state's large agency fleet are planning to utilize hydrogen fuel cell buses for their compliance strategy, which is a significant increase from the 1% fuel cell bus adoption assumed by CARB when the ICT rule was passed.[151] This could signal both greater confidence in the anticipated performance of fuel cell electric buses, as well as concerns in battery-electric bus range, weight, fueling, and increased cost and fueling complexity.

> **"We have seen great stride in the advancement of hydrogen fuel cell vehicles over the past eight years, but more advancements are needed to make the vehicle at or near parity of diesel vehicles."**
>
> — Tony Williamson, Director, Compliance & Sustainability, TTSI, California

First Pre-Commercial Tractor Products Arriving at Fleets This Year

The past year saw the largest Class 8 FCEV tractor deployments and purchases in the U.S. to date. At least 10 of Kenworth's proof-of-concept T680 fuel cell tractors began drayage operations between the Port of Los Angeles and the Inland Empire with fleets TTSI, UPS, and Toyota Logistics. These trucks feature fuel cell stacks from Toyota and are supported by two purpose-built hydrogen fueling stations developed by Shell in Wilmington and Ontario, California. Toyota has separately developed a private fueling facility at its terminal at the Port of Long Beach to support deployment of its trucks and passenger cars.

The Class 8 tractor segment also saw 80 grant-funded purchases of FCEVs in 2021 in the U.S., 50 of which were from new market entrant Hyzon.[152] The manufacturer, founded in 2020, reportedly delivered nearly 90 hydrogen fuel cell MD/HD vehicles to customers in Asia over the course of 2021, but delivery of Hyzon's first demonstration vehicle for Southern California-based drayage fleet TTSI was delayed until sometime in 2022.[153]

Hyundai also received funding for two pilots of its FCEV Class 8 tractor truck in the U.S. The pilot model is based on Hyundai's Xcient fuel cell cargo truck, of which more than 50 are already operating in Europe, Asia, and New Zealand. The U.S. model is expected to offer a 500-mile range. The first Hyundai pilot project deployed two FCEVs in the last half of 2021, with a fleet running long-haul freight operations between Southern and Northern California for 12 months.[154] The trucks will fuel at a select network of three FirstElement Fuel hydrogen stations already located throughout California. FirstElement, which lays claim to the largest hydrogen fueling network in the world, has constructed several stations in the region primarily to support the LDV segment.[155] Even though the FirstElement stations are primarily designed to support LD FCEVs, this project will help future development plans to provide public hydrogen fueling options for commercial fleets.

The second Hyundai pilot, NorCAL ZERO, will be the largest Class 8 on-road FCEV deployment in the U.S. to date.[156] The trucks will feature changes made to the vehicle based on the initial demonstration, with 30 units slated to deploy with partner Glovis America by the first half of 2023. The project includes the development of a high-capacity hydrogen fueling station in Oakland, California, designed to support as many as 50

[151] GNA analysis of Innovative Clean Transit Regulation and large transit agency roadmaps published as of December 2021.

[152] The State of Sustainable Fleets methodology for counting purchases and deliveries treats public incentive awards as a proxy for sales given that most awards result in a contract requirement to purchase and operate the vehicles.

[153] Hyzon Newsroom, "HYZON TO PROVIDE HYDROGEN-POWERED FUEL CELL TRUCK FOR COMMERCIAL VEHICLE TRIAL WITH TOTAL TRANSPORTATION SERVICES," 11 August 2021, accessed at https://hyzonmotors.com/hyzon-to-provide-hydrogen-powered-fuel-cell-truck-for-commercial-vehicle-trial-with-total-transportation-services/.

[154] Green Car Congress Newsroom, "Hyundai bringing XCIENT Fuel Cell trucks to California," 27 July 2021, accessed at https://www.greencarcongress.com/2021/07/20210727-xcient.html.

[155] FirstElement Fuel, "FirstElement Fuel, the largest hydrogen fueling network in the world, closes Series D round of $105 million," PR Newswire, 8 November 2021, accessed at https://www.prnewswire.com/news-releases/firstelement-fuel-the-largest-hydrogen-fueling-network-in-the-world-closes-series-d-round-of-105-million-301418137.html.

[156] Hyundai Newsroom, "Hyundai's XCIENT Fuel Cell Hitting the Road in California," 26 July 2021, accessed at https://www.hyundainews.com/en-us/releases/3362.

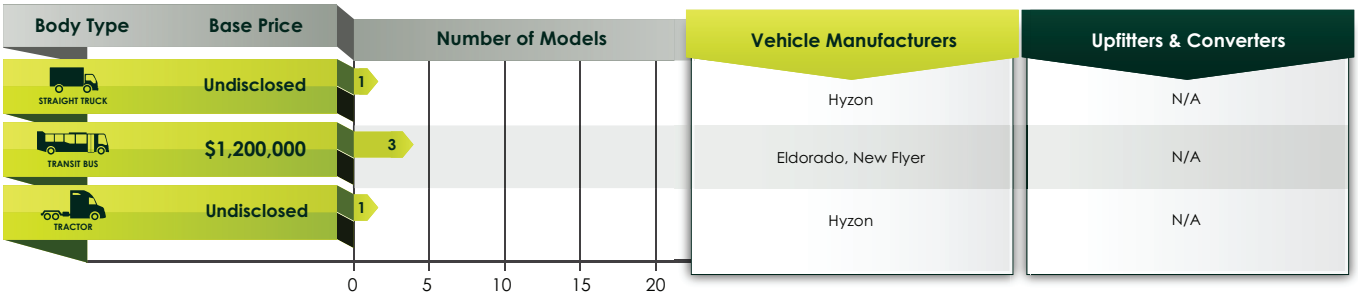
trucks with capacity to meet 30 kg of fuel demand per day.

The first two of Nikola's Tre FCEVs traveled from Arizona to California in early 2022, where they supported an Anheuser-Busch delivery to Super Bowl LVI in Los Angeles.[157] A unit was also delivered in early 2022 to Biagi Bros., and an additional two units are planned for drayage service with TTSI alongside two of the company's BEV Tre models.

The number of FCEVs advertised as commercially available from OEMs has doubled since 2020, driven primarily by Hyzon (Figure 9). The number of MD FCEVs now available dwindled from five advertised models to one available model, signaling the MD market segment is not likely a good fit for FCEVs.[158]

THE HYDROGEN FUEL CELL ELECTRIC VEHICLE MARKET

MD and HD FCEVs (Limited to Full Production)



MD and HD FCEVs (Announced to Active Demonstration)

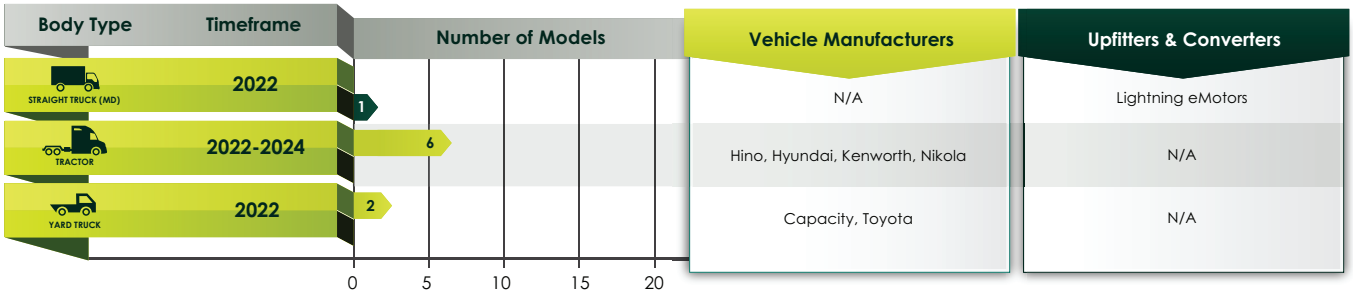


Figure 9: FCEVs offered by OEMs, upfitters, or converters producing new-build vehicles.

Station Costs Dropping, Utilization Increasing with Government Support

The average retail price of hydrogen at passenger vehicle fueling stations declined approximately 3% on average between Q3 2020 and Q2 2021, remaining above $16/kg.[159] This remains twice the state's target cost for gasoline parity of $8/kg.

While no significant drop in hydrogen prices has been publicly reported in 2021, costs for station builds, a key capital cost for hydrogen fueling, are falling. The third round of awards under the CEC's Hydrogen Refueling Infrastructure program suggests that the cost per kg for hydrogen fuel station development continues to decline in

[157] Ohnsman, Alan, "Nikola Kicks Off Hydrogen Truck Tests with Pre-Super Bowl Beer Runs for Anheuser-Busch," Forbes Magazine, 11 February 2022, accessed at https://www.forbes.com/sites/alanohnsman/2022/02/11/nikola-kicks-off-hydrogen-truck-tests-with-pre-super-bowl-beer-runs-for-anheuser-busch/?sh=70a733da5f87.

[158] Nikola Newsroom, "Nikola Delivers First Nikola Tre Battery-Electric Trucks to Total Transportation Services Inc.," 17 December 2021, accessed at https://nikolamotor.com/press_releases/nikola-delivers-first-nikola-tre-battery-electric-trucks-to-total-transportation-services-inc-143.

[159] California Air Resources Board and California Energy Commission," Joint Agency Staff Report on Assembly Bill 8: 2021 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California," December 2021, page 19, https://www.energy.ca.gov/sites/default/files/2021-12/CEC-600-2021-040.pdf.

California. Although this data is mostly for LDV stations, the cost per kg of daily station capacity has dropped 65% since the program's first awards in 2015, to $847/kg of capacity in 2021, according to the CEC.[160] These improvements reduce the capital cost of the station, particularly for the large stations that will be required to serve the MD and HD truck markets.

The average retail price of hydrogen at passenger vehicle fueling stations declined approximately 3% on average between Q3 2020 and Q2 2021, remaining above $16/kg.

Increased station utilization is also essential to building the market. In 2018, utilization of California's network was approaching 40%, and although this dipped in 2020, several station operators reported in 2021 that utilization had rebounded and was even approaching 100%.[161] The state calculates average utilization by dividing total annual demand by the capacity of stations across the state with consideration for funded and future stations.[162]

Continued growth within his sector will help drive down station capital costs in the coming years. The CEC's latest funding round fundamentally changed the outlook for hydrogen fueling network deployments in California, according to CARB. By requiring proposals to demonstrate multi-year, multi-station plans, the CEC's intentions are clear — a robust fueling infrastructure plan to drive economies of scale and encourage increased vehicle sales by OEMs.[163]

Fueling Stations Expand with Growth Outside of California on the Horizon

While available hydrogen fueling capacity doubled from 2020 and is expected to double again in 2022, nearly all public hydrogen fueling stations are still located in California. Most of the 48 stations existing prior to June 2021 were designed to serve the passenger car market, while most of the 128 new stations projected are designed to serve LD and MD vehicles, with some also serving HD vehicles.[164] California's 2021 hydrogen station development did not quite meet CARB's original goal for the year, but investments from the CEC and private parties point to continued growth through 2027.

California's hydrogen fueling station count increased to 52, with 48 new stations open throughout the state as of June 2021. This number is short of the 62 stations that CARB projected in 2020. Funding awards from the CEC announced in late December 2020 will add up to 94 new hydrogen stations and upgrade four existing

"The opportunity for heavy-duty, hydrogen fuel cell vehicles in regional and eventually long-haul applications is real. All zero-emission vehicles have their challenges to overcome, and with hydrogen, the infrastructure of producing and, when necessary, transporting, clean hydrogen stands out."

— Guy Welton, Director of Operations, Werner, Nebraskaa

[160] California Air Resources Board, "2021 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development.," September 2021, Page 4.

[161] Ibid, page 17.

[162] Footnote from CARB: "Note that this analysis is statewide and does not consider the details of individual station utilization. The methodology considers the capacity of stations to be funded and built in the future, and divides demand between funded and future stations proportionally to the total capacity within each group."

[163] Ibid, page 4.

[164] Leighty, Wayne, Hydrogen Commercial Manager, North America at Shell, via email, 18 April 2022.

stations, while private funds will add another 23 stations. California projects 100 hydrogen stations open by the end of 2023.[165] By 2026, the state anticipates that 176 hydrogen fueling stations will be operating with the capacity to serve passenger as well as MD commercial fleet customers. Shell alone has committed to 51 new hydrogen stations in California, including by installing hydrogen infrastructure at 48 existing Shell stations.[166] Most hydrogen station growth in California is concentrated in the greater Los Angeles and Bay Area markets, with projected capacity in the Inland Empire, a major goods movement region, the next area of growth.[167]

While available hydrogen fueling capacity doubled from 2020 and is expected to double again in 2022, nearly all public hydrogen fueling stations are still located in California.

Beyond California, new private investment commitments towards hydrogen infrastructure continued in 2021 with an MOU signed by BlackRock Renewable Power, NextEra Energy Resources, and DTNA as detailed previously.[168] The joint funding of $650 million will build a national, high-performance charging and fueling network for both MD and HD BEVs and FCEVs in the U.S. While no other public hydrogen stations were reported opening elsewhere in the U.S. as of February 2022, an additional 57 were reported

California continues to lead in terms of public investment, private capital, and partnerships aimed at developing hydrogen fueling infrastructure throughout the state with an increasing level of activity happening in 2021.

as planned by the AFDC.[169] Several are being planned nationally, including in Ohio, New York, Rhode Island, Connecticut, Massachusetts, and California.

California continues to lead in terms of public investment, private capital, and partnerships aimed at developing hydrogen fueling infrastructure throughout the state, with an increasing level of activity happening in 2021.

Equilon Enterprises, a subsidiary of Shell Oil, received a CEC grant to develop and demonstrate the first public retail multi-modal hydrogen refueling station in California, which aims to achieve diesel-like cost parity servicing on-road HD FCEVs as well as locomotives near the Port of West Sacramento. FirstElement opened several additional fueling stations throughout the state targeting commuters and received $105 million in a Series D funding round at the end of the 2021 to support its goal of expanding its network from 31 to 80 hydrogen stations in the state by 2024.[171] At least 12 are intended to support HD trucks as well as passenger cars.

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[165] Ibid, page 8.

[166] Shell Newsroom, "Shell to Expand California Hydrogen Refueling Infrastructure," 10 December 2022, accessed at https://www.shell.us/media/2020-media-releases/shell-to-expand-california-hydrogen-refueling-infrastructure.html.

[167] Ibid, Page 45.

[168] NextEra Energy Newsroom, "Daimler Truck North America, NextEra Energy Resources and BlackRock Renewable Power Announce Plans to Accelerate Public Charging Infrastructure for Commercial Vehicles Across The U.S.," 31 January 2022, accessed at https://newsroom.nexteraenergy.com/news-releases?item=123840.

[169] Alternative Fuels Data Center, "Alternative Fueling Station Locator," downloaded 7 February 2022, accessed at https://afdc.energy.gov/stations#/find/nearest.

[170] Green Car Congress Newsroom, "Cal Energy Commission awards Shell $4M to develop and demonstrate multi-modal hydrogen refueling station; road and rail," 13 August 2021, accessed at https://www.greencarcongress.com/2021/08/20210813-shell.html.

[171] FirstElement Fuel, "FirstElement Fuel, the largest hydrogen fueling network in the world, closes Series D round of $105 million," PR Newswire, 8 November 2021, accessed at https://www.prnewswire.com/news-releases/firstelement-fuel-the-largest-hydrogen-fueling-network-in-the-world-closes-series-d-round-of-105-million-301418137.html.

An innovative partnership between Nikola and TravelCenters of America will install HD truck fueling stations at two Southern California locations, slated to start operating in Q1 2023.[172]

Iwatani and Chevron agreed to co-develop and construct 30 hydrogen fueling sites in California by 2026 at Chevron-branded retail locations. While initially intended to service the LD market, station design will reportedly be flexible to eventually support HD FCEV needs.[173]

Overall fuel capacity projection in California by CARB for 2021 was 34,000 kg/day, more than double the prior year's forecast of 14,500 kg/day.

Hydrogen Production Commitments Proliferate, Renewables Dominate Early Production

Commitments to produce hydrogen fuel have grown significantly the last several years, mostly for the LDV market, with renewable hydrogen leading in California to date. Overall fuel capacity projection in California by CARB for 2021 was 34,000 kg/day, more than double the prior year's forecast of 14,500 kg/day.[174] Two of the leading producers in that market, FirstElement and Shell, advertised that they achieved 100% zero CI hydrogen in California in 2021. According to the state's LCFS program, as much as 92% of the hydrogen dispensed from California fueling stations reporting to the program was also renewable.[175]

As more operators open facilities, CARB does not anticipate that all hydrogen producers will make similar commitments.[176]

Synergies between renewable fuel markets for RNG, RD, and hydrogen continue to solidify. RNG is now the primary feedstock for hydrogen production in California, where 98% of CNG vehicle fuel used in the state is renewable.[177] Growing investment in and production of RNG creates more potential feedstock for hydrogen, although hydrogen producers will have to compete with other RNG end users for this feedstock. In 2021, RD production expanded significantly, a trend which has the potential to drive demand for lower carbon, renewable hydrogen as a feedstock for RD. Decarbonized hydrogen enables RD producers to achieve a lower CI for RD, increasing their dollar per gallon in LCFS revenue in California and states with similar programs.

With several proposed large-scale fuel supply projects recently announced across the U.S., renewable hydrogen production is on a growth trajectory, supporting sectors beyond transportation. One such project is Hy Stor Energy's plan to build the country's largest renewable hydrogen hub in Mississippi, aiming to produce 110,000 metric tons annually. The facility will use underground salt caverns to store another 70,000 metric tons in its first year of operations, 2025. If approved, the project's production and storage capacity would be more than 10 times the size of the joint Intermountain Power and Advanced Clean Energy Storage projects — the previously largest planned U.S. project, which is expected to come online in 2025 to supply hydrogen for power generation in Los Angeles.[178]

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[172] Smith, Jennifer, "TravelCenters of America to Add Hydrogen Fueling Sites for Big Rigs," The Wall Street Journal, 22 April 2021, accessed at https://www.wsj.com/articles/travelcenters-of-america-to-add-hydrogen-fueling-sites-for-big-rigs-11619125565?mod=djemlogistics_h.

[173] Business Wire, "Chevron, Iwatani Announce Agreement to Build 30 Hydrogen Fueling Stations in California," 24 February 2022, accessed at https://www.businesswire.com/news/home/20220224005447/en/Chevron-Iwatani-Announce-Agreement-to-Build-30-Hydrogen-Fueling-Stations-in-California.

[174] Business Wire, "Chevron, Iwatani Announce Agreement to Build 30 Hydrogen Fueling Stations in California," 24 February 2022, accessed at https://www.businesswire.com/news/home/20220224005447/en/Chevron-Iwatani-Announce-Agreement-to-Build-30-Hydrogen-Fueling-Stations-in-California.

[175] California Air Resources Board, "2021 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development," September 2021.

[176] True Zero Newsroom, "True Zero News," downloaded 7 February 2022, accessed at https://www.truezero.com/stories/.

[177] California Air Resources Board, "2021 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development," September 2021, Page 58. Leighty, Wayne, Hydrogen Commercial Manager, North America at Shell, via email, 8 February 2022.

[178] Intermountain Power Agency, "IPP Renewed," downloaded 7 February 2022, accessed at https://www.ipautah.com/ipp-renewed/.

Several other fuel production projects that have been announced or in development will bring a mix of renewable and fossil-based hydrogen to market. Nikola entered several agreements with partners in the Midwest to develop large-scale hydrogen production facilities with a focus on low or no carbon fuel, including a project to produce green hydrogen for transportation fuel and baseload electricity generation and another to produce renewable hydrogen from RNG.[179,180] An Air Liquide plant announced in 2019 to serve the West Coast with liquid hydrogen sufficient to fuel 40,000 vehicles per day by 2025 is going through commissioning in 2022. When finished, the project, located in North Las Vegas, will produce a mix of fossil and renewable hydrogen.

Hyzon, which led HD FCEV truck purchases in 2021, has at least one MOU that will lay the groundwork for a joint venture between Hyzon and Wyoming-based waste-to-energy producer Raven SR to build as many as 100 hydrogen production facilities across the U.S. and globally.[182]

Hydrogen Industry Aligning to Streamline and Stimulate Growth

Hydrogen industry stakeholders, including OEMs, are actively developing standardized fueling equipment and collaborating to build the market. Two consortiums launched projects to develop and test standards for fuel cell modules and hydrogen fueling equipment. The European Fuel Cells and Hydrogen Joint Undertaking launched these projects in mid-2021.[183] The Hydrogen Heavy Duty Vehicle Industry Group (Air Liquide, Hyundai, Nel, Nikola, Shell, and Toyota) signed agreements to manufacture.[184] Testing was due to begin in late 2021. These are expected to reduce both time and cost for project deployment as a result of streamlined permitting, commissioning, and equipment compatibility.

A new coalition of 11 companies in the hydrogen value chain, including Shell, Toyota, and Cummins, formed Hydrogen Forward to promote the benefits of hydrogen.

Chevron entered separate agreements with Toyota and Cummins to advance hydrogen for the commercial transportation segment.[185] In these relationships, the parties are integrating and aligning efforts for technology development and growth of market demand for FCEV solutions. Also in 2021, a new coalition of 11 companies in the hydrogen value chain, including Shell, Toyota, and Cummins, formed Hydrogen Forward to promote the benefits of hydrogen.[186] They join existing advocacy groups the California Hydrogen Business Council and the California Fuel Cell Partnership working to build the foundation of the industry in the state. This early alignment of fuel producers and component and vehicle manufacturers is critical to ensuring integration of technology as the industry matures.

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[179] Nikola Corporation: Wabash Valley Resources LLC, "Nikola Invests $50 Million In Wabash Valley Resources To Produce Clean Hydrogen In The Midwest For Zero-Emission Nikola Trucks," PR Newswire, 22 June 2021, accessed at https://www.prnewswire.com/news-releases/nikola-invests-50-million-in-wabash-valley-resources-to-produce-clean-hydrogen-in-the-midwest-for-zero-emission-nikola-trucks-301317805.html.

[180] Green Car Congress Newsroom, "Nikola and OPAL Fuels to co-develop and construct hydrogen fueling stations and related infrastructure for Class 8 FCEVs," 1 October 2021, accessed at https://www.greencarcongress.com/2021/10/20211001-nikola.html.

[181] AirLiquide Newsroom, "Hydrogen mobility on the West Coast: Air Liquide's response to a growing demand in the United States," 4 January 2022, accessed at https://www.airliquide.com/stories/hydrogen/hydrogen-mobility-west-coast-air-liquides-response-growing-demand-united-states.

[182] Hyzon Newsroom, "HYZON MOTORS' PARTNER, RAVEN SR, INC. ANNOUNCES ITS FIRST WASTE-TO-HYDROGEN HUB," 24 August 2021, accessed at https://www.hyzonmotors.com/in-the-news/hyzon-motors-partner-raven-sr-inc-announces-its-first-waste-to-hydrogen-hub.

[183] Heavy Duty Trucking Newsroom, "Global News Roundup: Hydrogen Fuel Cell Truck Development," 18 May 2021, accessed at https://www.truckinginfo.com/10143798/global-news-roundup-hydrogen-fuel-cell-truck-development.

[184] Green Car congress Newsroom, "Hydrogen Heavy Duty Vehicle Industry Group signs agreements to industrialize 70 MPa high-flow refueling; H70HF," 9 October 2021, accessed at https://www.greencarcongress.com/2021/10/20211009-h70hf.html.

[185] Heavy Duty Trucking Newsroom, "Chevron, Cummins To Collaborate on Hydrogen Advancement," 15 July 2021, accessed at https://www.truckinginfo.com/10147411/chevron-cummins-to-collaboration-on-hydrogen-advancement.

[186] Hydrogen Forward, ""Hydrogen Forward" Coalition Formed to Advance Hydrogen in the U.S.," PR Newswire, 2 February 2021, accessed at https://www.prnewswire.com/news-releases/hydrogen-forward-coalition-formed-to-advance-hydrogen-in-the-us-301219726.html.

Major Technology Gaps Must be Overcome to Achieve Scale

The IEA observed in late 2021 that commitments of $337 billion in public and private investment to build global electrolyzer capacity, a critical technology in one of the leading hydrogen fuel production processes, are insufficient despite investment growth.[187] Reducing the cost and increasing availability of this important piece of equipment remains a key challenge in achieving affordable hydrogen prices, including renewable hydrogen.[188]

A 2021 study from Center for Transportation and the Environment (CTE) observed that hydrogen fuel distribution systems are limited but have an opportunity to leverage existing natural gas pipelines to reach more fleets in the future. There are more than 1,600 miles of hydrogen pipelines owned by industrial merchant gas companies, but they supply very few hydrogen refueling stations.[189] Instead, most stations are served by delivery trucks transporting tanks of hydrogen in either gaseous or liquid form. CTE observes that existing CNG stations served by natural gas pipelines could be retrofitted for hydrogen production and retail. Upgrades would need to be made with compressors to achieve the necessary fueling pressure, and new permitting would also be required.

> **"We purchased five new hydrogen fuel cell buses in 2021 and put them into service in October 2021. It's been a rough start. The vehicles are not performing to expectation and are frequently out of service. It appears to be mostly software issues with the bus and not fuel cell problems."**
>
> — Chris James, Director of Maintenance, Golden Empire Transit District, California

Fleet Insights: FCEVs

With the technology still in the early stages of commercialization, only 12 fleets reported using MD or HD FCEVs in the 2022 annual fleet survey. These 12 fleets unanimously report emission and noise reduction benefits, while most also report odor reduction (92%), torque improvement (83%), and driver satisfaction (83%).[190] Predictably, top challenges among surveyed fleets include vehicle cost (92%), as well as fuel cost and supply (75%).

Among the dozen fleets that have demonstrated FCEVs, nearly all (92%) intend to continue to pilot or purchase FCEVs in the next year.

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Private infrastructure is a critical aspect of early demonstrations given the minimal public hydrogen infrastructure available for MD and HD fleets. Less than half (42%) of fleets surveyed intend to pilot or purchase hydrogen fueling infrastructure. Given the very early state of the market, preferred fueling options by fleets are still to be determined.

About 30% of fleets that have piloted FCEVs say they will install on-site non-renewable hydrogen production, while a quarter intend to produce hydrogen on-site from renewable sources in the next 12 months. The remaining fleets will use off-site fueling infrastructure.

While these data points provide a glimpse of end-user experiences, more fleets operating FCEVs are needed to offer greater insight into the direction of adoption by commercial MD and HD vehicle operators.

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[187] Penrod, Emma, "IEA: $1.2 trillion in low-carbon hydrogen funding needed to reach global net zero emissions by 2050," Utility Dive, 5 October 2021, accessed at https://www.utilitydive.com/news/iea-12-trillion-in-low-carbon-hydrogen-funding-needed-to-reach-global-ne/607667/.

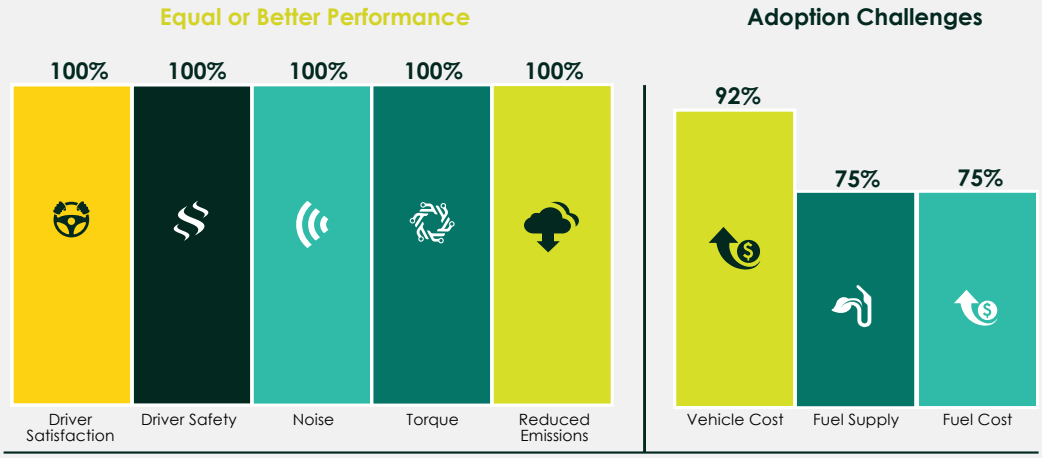
[188] Edwardes-Evans, Henry, "Green hydrogen costs need to fall over 50% to be viable: S&P Global Ratings," S&P Global, 20 November 2020, accessed at https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/112020-green-hydrogen-costs-need-to-fall-over-50-to-be-viable-sampp-global-ratings.

[189] Center for Transportation and the Environment, "Hydrogen Infrastructure Integration Study," 2021.

[190] Given the small sample size of fleets who have piloted MD and HD FCEVs and the early state of vehicle development, no chart on performance and adoption results was prepared in 2022.

PERFORMANCE AND ADOPTION RESULTS REPORTED BY FCEV USERS

Percent of FCEV users surveyed who cite a criteria as equal/better or an adoption challenge compared to diesel and gasoline.



Source: Percent of surveyed early adopter fleets that have either piloted or purchased MD or HD FCEVs who cite a criteria as either equal/better or a challenge from the State of Sustainable Fleets 2022 survey.

California Hydrogen Business Council

Industry Perspective: California Hydrogen Business Council (CHBC)

The hydrogen fuel cell transportation market is continuing to accelerate rapidly. In the last 12 months, Class 8 tractors manufactured by Toyota/Kenworth, Nikola, Hyundai, Cummins, and Hyzon were under demonstration in California and 169 fuel cell transit buses are either on order or in operation nationally, up from 87 in 2020. Overall vehicle orders quadrupled across the transit and HD tractor segments, with the largest demonstrations and orders for Class 8 fuel cell trucks in the U.S. to date underway.

Transit continues to lead HD FCEV adoption by vehicle count, a trend expected to continue. California transit agencies that are required to transition to ZEVs are choosing FCEVs in much higher numbers than predicted. In another early adopter segment, many MD and HD truck deployments are coming in the near- and mid-term as OEMs continue to deliver on big announcements: 1,600 Hyundai fuel cell electric trucks in Switzerland by 2025, 30 Hyundai fuel cell electric trucks in California by 2023-2024, and Nikola receiving letters of intent from large customers to purchase a total of 200 ZE trucks.

Upstart hydrogen producers working tirelessly to deploy new and updated hydrogen production technologies are driving innovation. Many use low-carbon renewable feedstocks that will reduce the cost of hydrogen to a level that makes the TCO work for fleets and spur further FCEV deployment. This pressures the incumbent industrial gas companies to find ways to be price competitive as the market for hydrogen matures. Recent announcements from Plug Power, Air Liquide, Air Products, and Linde related to liquid hydrogen fueling production sites for 10-30 tons of hydrogen production per day in or near California show expectations of greater demand for hydrogen fuel.

Dispensed hydrogen must reach around $5-6/kg to compete with today's diesel prices, given the efficiency of fuel cell drivetrains, even with the uptick in oil prices. These price levels can be achieved through hydrogen consumption at scale, especially with California's LCFS program incentivizing the use of low- and negative-carbon hydrogen for transportation. New federal funding dedicates $1B for the Clean Hydrogen Electrolysis Program to reduce hydrogen production costs to $2/kg by 2026.

A fleet of 20 fuel cell tractors will consume around 1,000kg/day. Companies looking to produce hydrogen are considering capacities up to 30,000kg/day across California and around the rest of the country. While no public hydrogen stations were opened outside of California in 2021, private investments are expected to launch infrastructure along transportation corridors around the country, especially as the U.S. DOE launches the Hydrogen Hub program with $8 billion in funding, as well as $500 million for Clean Hydrogen Manufacturing and Recycling. Currently, 100 public stations are expected to be operational in California by 2023, and 200 stations between 2025 and 2026. Additional stations, primarily for LDVs, are planned for Ohio, New York, Rhode Island, Connecticut, and Massachusetts.

Overall fleets can expect costs for FCEVs and hydrogen to decline in 12-24 months while station counts rise, especially as demand grows from adoption and increased production of vehicles. Combined with funding programs that support significant market development, like California's HVIP that can provide up to $270,000 for a Class 8 drayage, hydrogen is an opportunity for fleets to meet their ZE and operational goals as early as 2023.

[191] Hyzon Motors Newsroom, "Hyzon Motors and TC Energy Announce Modular Hydrogen Production Hub Development Agreement," 10 November 2021, accessed at, https://www.hyzonmotors.com/in-the-news/hyzon-motors-and-tc-energy-announce-modular-hydrogen-production-hub-development-agreement.

[192] California Governor's Office of Business and Economic Development, "Hydrogen Fueling Station Progress," downloaded 24 April 2022, accessed at, https://business.ca.gov/industries/zero-emission-vehicles/hydrogen-fueling-station-progress/.

CONCLUSION AND KEY FINDINGS

A fundamental shift away from gasoline- and diesel-based transportation has begun. Major market and regulatory forces during 2021 and early 2022 are creating a "perfect storm" that is driving an accelerated transition to clean vehicles and fuels. Billions of dollars of public and private sector investments have been made, a growing number of ambitious GHG reduction goals and policies are being put into place, and an increasing zero-emission regulatory framework are all combining to hasten the transition that will occur in the coming decades. A strong foundation for this transformation has been firmly established and transportation stakeholders recognize that they must continue the path forward to a more sustainable future.

Bold commitments to environmental sustainability and achieving net-zero GHG emissions have been made by some of the world's largest businesses and governments over the last 24 months, with most of these commitments setting their targets for the 2040 to 2050 timeframe — and some even sooner. Globally, organizations are now moving from goal setting to the development and execution of strategies and management practices that will allow them to meet their ambitious objectives.

Given the scale of these commitments, and the relatively short time required to meet them, entities must focus on the largest sources of their GHG emissions. In doing so, they are confronting the reality that fleets must reduce GHG emissions by as much as 80-100% by 2050 to reach science-based or net-zero targets, reductions that cannot be achieved via incremental improvements to petroleum-based technologies. To achieve these levels of emission reductions, a combination of clean and efficient vehicles, ultra-low carbon renewable fuels, and zero-emission technologies will be required.

As the industry begins its emissions reduction journey, RD has been an incredibly important and successful tool that can be implemented. This low-carbon, drop-in fuel enables fleets to quickly achieve significant GHG emission reductions using their existing fueling and vehicle assets. Subsequently, growth in demand has been significant, and forward production, supply, and the likely use of RD is expected to see strong uptake.

While RD's growth trajectory is a positive sign and offers fleets a near-term option, criteria emissions from diesel vehicles are becoming increasingly regulated. These regulations will make the technology more expensive, more complicated to operate and maintain, and less efficient, resulting in higher GHG emissions. Coupled with very high diesel prices, the increased costs of operating diesel technology soften the incremental costs of near-zero and zero-emission vehicles, making them more attractive to end users. Furthermore, moves by California and 11 other states and the District of Columbia to adopt regulations that will force the transition to ZEVs in the next two decades will add even greater incentive for fleets to implement technologies other than diesel. Even with the immediate GHG benefits provided by RD, these regulations and aggressive commitments to science-based or net-zero targets will drive a transition away from petroleum-based technologies.

Among established clean vehicle technologies, NGVs realized modest gains in vehicle sales in 2021, and the market is poised for even more growth in the years ahead. The increasing availability of ultra-low carbon RNG in California and nationally and significant fuel savings compared to diesel, as well as a newly announced 15-liter natural gas Cummins engine that enables a wider spectrum of HD fleets to adopt, will provide a powerful driver for increased fleet adoption. Leading fleets with existing natural gas truck programs report high rates of satisfaction across critical sustainability, economic, and operational factors.

Sales for propane vehicles declined in 2021, but demand for propane fuel in the transportation sector reached an all-time high. Even with fuel prices increasing in 2021, propane remains significantly more price-competitive than gasoline and diesel. Renewable propane will become more important for fleets that are seeking increased GHG reductions, and expanded RD production could increase the domestic supply of renewable propane, as it is a co-product of RD. A newly announced 6.7L engine from Cummins is slated to expand propane technology to new markets that previously did not have access to the technology. Like the natural gas sector, superior economics, renewable fuel and low GHG emissions, and an increasing array of applications that can be served by propane vehicles are expected to contribute to continued market demand for this technology.

The past year realized historic investment by many of the world's largest vehicle manufacturers and infrastructure providers to lay the foundation for future scale. Last year's report covered announcements by Ford and GM for multi-billion-dollar commitments to bring dozens of new battery-electric models to market; since that time, both have accelerated their production timelines. Nearly every major OEM has made a commitment to commercialize BEVs, and many have stated their intention to transition away from internal combustion engines entirely. To bridge the infrastructure gap, new partnerships formed in 2021 and 2022 intend to scale charging infrastructure nationally. A coalition of 51 investor-owned utilities committed to develop fast charging along major U.S. travel corridors, while an MOU by Black Rock Renewable Power, NextEra Energy Resources, and DTNA promises to commit $650 million to operate a nationwide, high-performance charging network for MD and HD BEVs.

Enthusiasm for electric vehicles by fleets remains high, though it may be the expanding regulatory landscape for ZEVs that ultimately pushes BEVs and FCEVs into wider fleet operations given the lack of clearly established TCO benefits for these technologies at this early stage. For example, orders quadrupled for HD FCEVs in 2021, totaling 143 vehicles, led by the transit sector which is regulated in California to move to zero emissions. In addition, dozens of grant-funded projects have helped to advance several projects where Class 8 fuel cell tractors will be deployed and tested in real-world operations. All public hydrogen fueling stations are now based solely in California, although among the 100 stations planned for the next few years, around a half dozen will be in other states.

With activity and investment greatly expanding, the foundation for the future sustainable fleet market is firmer than ever before. Clean fuel and commercial vehicle markets will continue to scale each year hereafter. The growth rates for each advanced technology and low-carbon fuel is to be determined by a combination of increased regulatory actions, and the ability to demonstrate sound economic and environmental sustainability benefits. Without question, it is increasingly clear that stakeholders across the commercial transportation sector will be working collectively toward achieving a common goal of steep emission reductions in the next two to three decades.

2022 KEY FINDINGS

Clean Technology is Accelerating

For the third consecutive year, nearly 85% of surveyed fleets who have gone beyond incremental steps by adopting alternative drivetrain technologies report that their use of clean vehicles and fuels will continue to grow. Such high and consistent outlook from early adopters demonstrates that these fleets garner exactly the high operational, cost, and emissions benefits that are needed in the new market reality. The following summarizes key trends from the State of Sustainable Fleets 2022 Market Brief.

KEY FINDING: California is the market starter, but clean transportation funding and policy is spreading nationally.

While the epicenter of the clean fleet transition is in California, a critical combination of public and private sector investment, aggressive commitments to sustainability and zero carbon goals, and zero-emission regulations is providing significant tailwinds to catalyze a holistic transformation of the U.S. commercial transportation industry. Soon after California passed its statewide rule mandating that vehicle manufacturers begin selling medium and HD zero-emission vehicles, 11 other states and the District of Columbia either passed or are considering adopting their own very similar version of this rule. Likewise, in 2021, California adopted the Low NOx Omnibus rule, which will require HD engines meet an ultra-low NOx emission standard of 0.02g/bhp-hr beginning in 2027, combined with additional warranty and useful life provisions. New NOx and GHG emissions standards proposed under the U.S. EPA's Clean Trucks Plan are, in part, based on California's rule.

Just a year after California's investor-owned utilities announced $750 million in funding to expand EV infrastructure in support of fleets, New York utilities nearly doubled that amount and similar utility programs are expanding nationally. The $1.2 trillion IIJA has an unprecedented clean technology emphasis, with several multi-billion-dollar

programs earmarked to transition fleet sectors to clean vehicles and expand national infrastructure including a regional hydrogen hub program and a dedicated program to support the development of a national EV charging network. Funding for clean vehicles and infrastructure has increased nearly seven-fold from an average of $3 billion to an expected $20 billion annually across the nation for at least the next few years.

KEY FINDING: CNG and propane no longer need funding for adoption, though both still benefit from many incentives.

Throughout 2021, CNG maintained a clear cost advantage and relative price stability when compared to a volatile year for diesel. Nationally, the price of CNG increased approximately 3% on average at public fueling in 2021 as compared to diesel prices that increased nearly 19% nationwide. The result for fleets using CNG the past year was an average 25% lower price of CNG on a DGE basis. The per DGE pump price remained competitive at $2.32 per DGE for private fuelers versus $2.57 per DGE at public fueling stations. Fleets that have embraced CNG realize clear economic benefits: 79% of fleets in the survey report fuel cost savings as a primary advantage with some fleets claiming ROI in as little as 2-3 years. Due to these economics and excellent performance in the right applications, CNG has experienced growth since 2017 and continued to lead in vehicle deliveries (as counted by registrations) among the clean drivetrains in this report.

The segments that drive propane vehicle sales – school, paratransit, delivery – have been harder hit by the pandemic, and therefore sales are down. Nonetheless, the technology is cost-effective with fuel that is sub-$2 per GGE and on-site fueling infrastructure that can be installed very quickly and at little cost. When asked about these benefits in the annual survey, 67% of fleets operating on propane report fuel cost savings as a benefit.

CNG and propane were the original favorites of policymakers and the agencies that administer incentives. Many air districts and local governments tasked with removing NOx and particulate matter emission from MD and HD vehicles evaluate technologies based on cost-effectiveness. With its relatively lower capital costs as compared to ZEVs, CNG and propane perform very well in these programs.

KEY FINDING: Battery-electric vehicle demand is ramping up despite supply chain delays and persistently high costs.

The report finds that scheduled HD BEV deployments will go from dozens to hundreds across this year and next. Increased fleet interest has resulted in a growing number of grant applications for BEVs and expected forthcoming orders. Some sectors already see early signs of scale, including nearly 1,800 battery-electric school buses now ordered or deployed by more than 350 school fleets across the U.S. A continued

focus on the benefits of clean technology for children's health by policymakers and funding agencies is expected to expand scale for the school sector, with the State of New York's new rule that passed during the writing of this report as the most recent example. It requires approximately 50,000 school buses in the state to transition fully to ZEVs by 2035, starting as early as 2027.

A few hundred Class 8 BEVs were funded in 2021 and 2022 that designate major manufacturers who will eventually be under contract to fulfill the orders. In the MD sector, both Ford and GM announced accelerated production timelines with Ford expected to produce 160,000 F-150 Lightning units in 2025, not necessarily all for fleets, but both announcing thousands of orders from big customers for their electric delivery vehicles that will largely go to fleets.

Fleet demand for BEVs continues to exceed availability, largely due to significantly limited production thus far, and prices remain stubbornly high. Although 170 BEV models have been advertised by OEMs, only 70% are available for customer order at the time of publication and far fewer are available for delivery. Battery costs, a critical driver of vehicle cost, remain high despite price drops in battery packs for LD vehicles in 2021. Charging costs also show signs of a similar holding pattern.

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KEY FINDING: Renewable diesel and renewable natural gas experience record growth with support from clean fuel programs.

Last year's report highlighted that RD was one of the fuels that petroleum producers prioritized for investment during COVID and noted several announcements for new production. Production capacity for RD increased from 600 to 800 million gallons between late 2020 and mid-2021. By 2025, U.S. capacity is forecasted to exceed 5 billion gallons per year — enough to support 10% of the country's current diesel demand.

RD maintained an approximately $1/gal incremental cost over diesel nationwide in 2021. In states with clean fuel programs, such as California, the financial offset

available via the LCFS allows for RD to be more competitively priced against diesel, thus driving a growth in end-user consumption. RD use in California increased approximately 50% between 2020 and 2021 to nearly 885 million gallons. The demand growth was also visible via the 84% increase in the volume of RD credits exchanged within the California LCFS program between Q1 2020 and Q4 2021.

Nationally, RNG production capacity increased by 24% from 2020 to 2021, enabling the U.S. to produce enough RNG fuel to displace nearly 574 million gallons of diesel annually. Last year, 64% of all natural gas used in on-road transportation nationally was RNG, up from 53% in 2020. In California, RNG has replaced nearly all natural gas consumption for transportation, comprising 98% of the natural gas reported in the state's LCFS program. California natural gas fuel consumption recovered in 2021 to nearly the same peak levels as in 2019. The emissions associated with RNG used by transportation in California dove further into negative territory: the energy weighted carbon intensity of all natural gas consumed in California for all of 2021 was -33.36 gCO2e/MJ, down from the -27.17 through the first three quarters of 2021. Production will continue to grow given 230 RNG projects that were projected to be in operation across the U.S. as of December 31, 2021 — 46% more than in 2020.

KEY FINDING: Hydrogen fuel cell vehicles edge ever closer to reality, with grant-awarded vehicles and planned stations more than doubling.

While no commercial FCEVs were delivered to fleet customers in 2021, vehicle orders quadrupled, largely driven by the transit sector. California transit agencies that are required to transition to ZEVs are planning to utilize FCEVs in higher numbers than predicted when the regulation first passed. At that time, it was assumed that only 1% of vehicles would be hydrogen, but rollout plans submitted by the largest transit agencies show a big jump to 18% of their ZEV deployments. Truck fleets also saw the first batch of grant-funded projects for dozens of fuel cell trucks that are expected to translate into orders. The Class 8 tractor segment saw 80 FCEVs that are expected be deployed near-term in the U.S. with grant-funds awarded in 2021.

No public hydrogen stations were opened outside of California in 2021, but public and private investments are expected to launch infrastructure along key transportation corridors in regions throughout the U.S. By 2026, California anticipates that 176 hydrogen stations will be operating with capacity to serve passenger as well as MD fleet customers. At least an additional 110 hydrogen stations for LD and MD vehicles and 16 stations for HD vehicles are planned to be developed in California, Ohio, New York, Rhode Island, Connecticut, and Massachusetts. Most of the 128 new hydrogen fuel stations projected are designed to serve LD and MD vehicles, with some also serving for HD vehicles. New private partnerships to develop infrastructure have announced that major highways will be a near-term focus for development.

METHODOLOGY

The State of Sustainable Fleets is the only comprehensive, technology-neutral analysis of adoption rates, fleet insights, and critical trends for advanced, clean fuels and technologies. The methodology combines primary data collected through surveys with secondary data collected from credible published sources, and expert analysis by clean transportation and energy consultants Gladstein, Neandross and Associates from its nearly three decades of clean technology work in the MD and HD vehicles and infrastructure market. This section describes the scope of study and the methodology for primary data collection and data procured directly from third parties. Publicly available data are cited throughout the report.

Scope of Study

This study looked at fleets currently operating Class 2-8 vehicles in the U.S. The survey targeted public and private fleets in several sectors: school, shuttle, state/county/municipal, urban delivery, refuse, utility, transit, regional-haul, long-haul, and new in 2022, off-road yard trucks. Renewable fuels considered in this study include renewable fuels and electricity for diesel, propane, natural gas, battery-electric, and fuel cell electric vehicles. Hybrid technologies were not studied in this report. The study's geographic scope is the U.S.

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, OEM sales data on propane vehicles with analysis by PERC, grant awards, California large transit agency Zero-Emission Bus Rollout Plans, press releases, and GNA's direct communications with fleets. GNA's vehicle availability data were created from information published by OEMs, upfitters, or converters producing new-build vehicles. These data do not account for fuel system manufacturers or other aftermarket providers that may repower existing vehicles. Models were counted by weight class — a product listed with two weight classes (e.g., GVWR 6/7) was counted as two models. In 2022, stripped chassis and yard trucks were added and cab-overs were removed. Average model prices are based on manufacturer-advertised base prices for alternative fuel vehicles in each segment, or where these prices are not available (as is especially the case with FCEVs), advertised diesel or gasoline model base prices were adjusted with industry-defined incremental values appropriate to each alternative fuel technology. BEV and FCEV prices account for differences in battery pack size. CNG and propane vehicle prices account for differences in tank size. Models are considered "Available" if the manufacturer had announced that it was in limited or full production, and "Advertised" if the manufacturer was at any development stage preceding limited production. Estimates of the number of vehicles in operation by fleet type are based on vehicle registration, order and deployment data, survey data of vehicle counts by fleet and technology type, and GNA's research on vehicle deployments by leading adopters.

Sponsors of the report — Penske Transportation Solutions, Daimler Truck North America, Shell Oil Company, and Cummins, 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 ideas and opinions expressed in the report do not necessarily represent those of the sponsors. The State of Sustainable Fleets 2022 Market Brief represents a comprehensive, technology-neutral analysis of the best data available today for on-road commercial fleets and offroad yard truck fleets. Future reports will update the analysis as new, credible data become available.

Survey Methodology

Surveys were used to identify trends and operational performance insights from early adopters of the four clean vehicle technologies (natural gas, propane, electric, and fuel cell electric), technologies for more sustainable use of baseline fleet vehicle technologies (diesel), and 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, and renewable hydrogen). Fleets were asked to compare each clean drivetrain technology they had piloted or purchased with their baseline technology of gasoline and/or diesel. The survey did not ask for comparisons between the clean vehicle technologies. Nearly 250 fleet responses were received in January and February 2022.

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