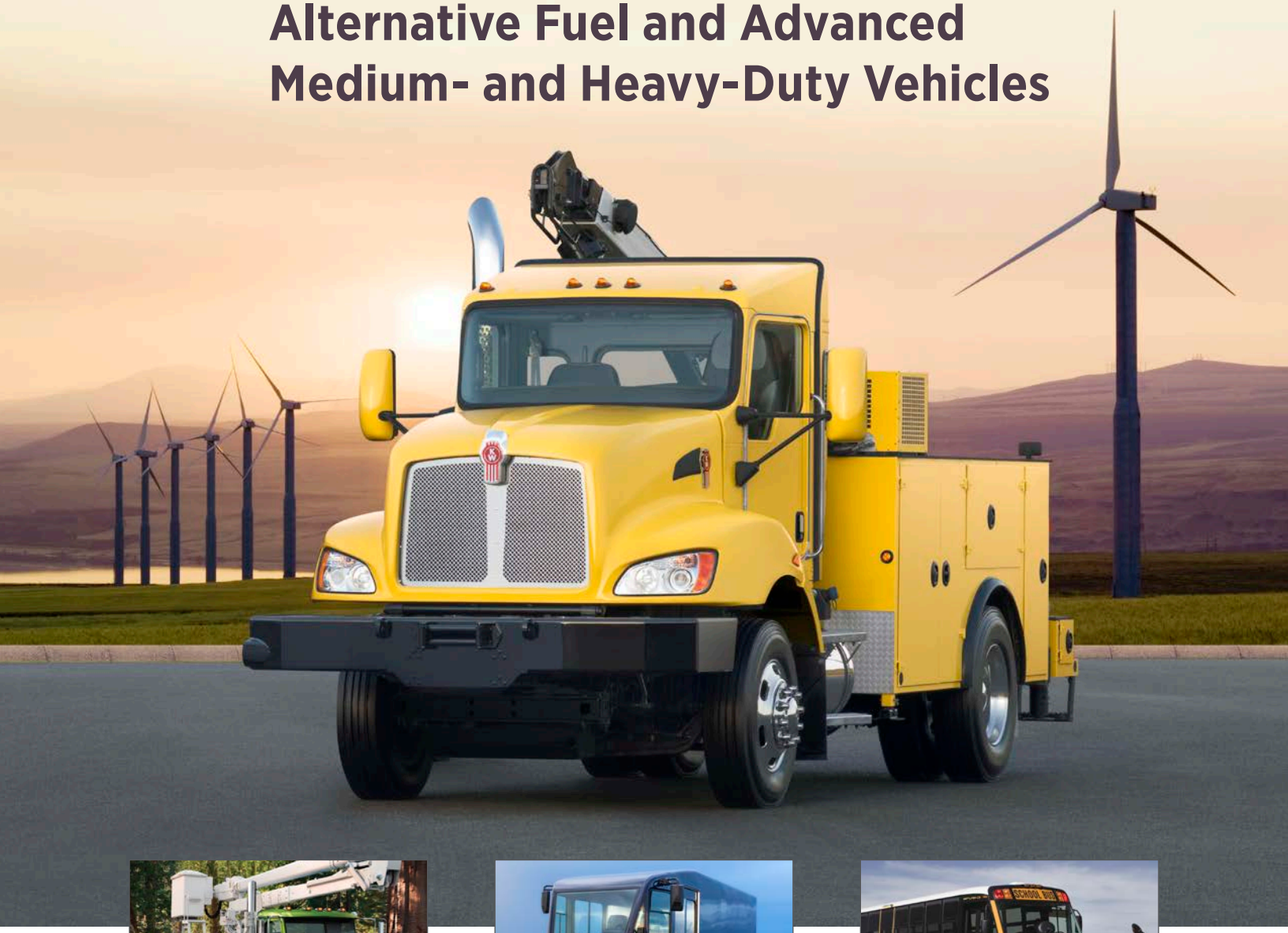
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Clean Cities Guide to

Alternative Fuel and Advanced Medium- and Heavy-Duty Vehicles



Clean Cities
U.S. Department of Energy

School Bus • Shuttle Bus • Transit Bus • Refuse Truck • Tractor • Van • Vocational Truck

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Photos, from top: North American Bus Industries, Kenworth, Turtle Top

Front cover photos, clockwise from top: Kenworth, Thomas Built Buses, Boulder Electric Vehicle, Peterbilt

About the Guide

Today's fleets are increasingly interested in medium- and heavy-duty vehicles that use alternative fuels or advanced technologies that can help reduce operating costs, meet emissions requirements, improve fleet sustainability, and support U.S. energy independence. Vehicle and engine manufacturers are responding to this interest with a wide range of options across a steadily growing number of vehicle applications.

This guide provides an overview of alternative fuel power systems—including engines, microturbines, and fuel cells—and hybrid propulsion systems. The guide also offers a brief overview of individual medium- and heavy-duty vehicles, listed by application. Notably, a transition to any alternative fuel or advanced technology is a long-term commitment that merits thoughtful research and planning, with attention to technical, economic, and geographical considerations. Clean Cities' Alternative Fuels Data Center (AFDC) offers a suite of tools that can aid a fleet in its analysis (*afdc.energy.gov/tools*).

Clean Cities collects the vehicle information presented in this guide from multiple sources, including original equipment manufacturers (OEMs), conversion companies, and product literature. Diligent effort was made to contact all manufacturers that offer commercially available vehicles with alternative fuel or advanced technology options. Manufacturers are also invited to send comments, additions, or corrections related to any information contained in the guide by contacting the AFDC webmaster at *afdc.energy.gov/progs/webmaster.php*. The AFDC's online heavy-duty vehicle database (afdc.energy.gov/vehicles/search/heavy) reflects product changes made or identified after publication.

Heavy-Duty Vehicle Application Overview

The following list provides an overview of popular alternative fuel and advanced vehicle options for several common applications:

School Bus | Compressed natural gas (CNG) and propane (also known as liquefied petroleum gas, or LPG) are popular alternatives to gasoline and diesel fuel for school buses. Hybrid electric buses and plug-in hybrid electric buses are also available.

Shuttle Bus | CNG, propane, hybrid electrics, and fuel cells are potential options for shuttle buses and large passenger vehicles that provide transportation on standard routes.

Transit Bus | Hybrid transit buses, along with those powered by CNG or liquefied natural gas (LNG), are available. Fuel cell demonstrations are also in progress.

Refuse Truck | Many fleets have refuse trucks with CNG engines, and they can even run on landfill gas where biomethane processing facilities are in operation. Regular routes and stop-and-go operation make refuse haulers a good application for hybrid operation as well. Hydraulic hybrid systems are well suited to refuse service.

Tractor | Diesel electric hybrids offer fuel-saving hybrid operation with the convenient availability of diesel. CNG and LNG systems are also attractive options.

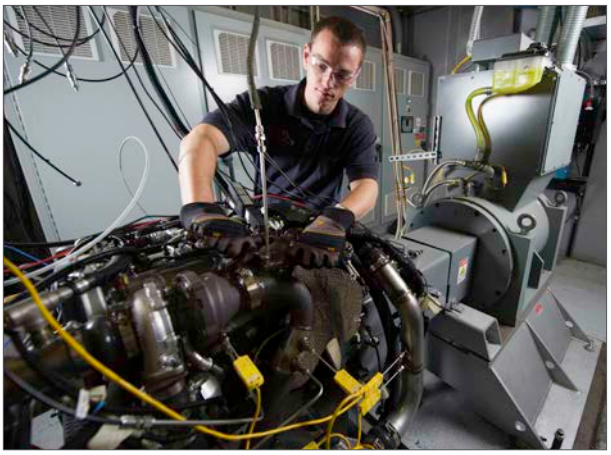
Van | Step vans that service a set route, such as a package delivery service, may find all-electric battery operation an effective alternative to conventional vans. CNG and propane operation are also popular alternatives.

Vocational Truck | CNG, LNG, propane, all-electric, and hybrid vehicles operate in a variety of roles, from beverage delivery to utility boom trucks, paint striping trucks, and merchandise delivery.

Heavy-Duty Emission Standards

The U.S. Environmental Protection Agency (EPA) and the California Air Resources Board (CARB) regulate vehicle emissions to reduce impacts to public health and the environment. These regulations apply to all vehicles, regardless of the fuels they operate on.

Emission standards are set based upon vehicle weight class. However, the emission certifications for heavy-duty vehicles apply to the engine rather than to the complete vehicle. A single engine can have multiple certifications if it can be used in vehicles of multiple weight classes. Notably, vehicle weight classifications vary from one regulatory agency to the next. For more information on emission standards, visit *epa.gov/otaq/hd-hwy.htm* and *arb.ca.gov/msprog/msprog.htm*.



Engine on a dynamometer at the National Renewable Energy Laboratory's ReFUEL facility. *Photo by Dennis Schroeder, NREL 22781*

Vehicle emissions fall into two categories:

- Air pollutants are smog-forming compounds and other emissions known to or suspected to cause serious health and environmental effects. These include particulate matter (PM), non-methane hydrocarbons (NMHC), sulfur oxides (SOx), and nitrogen oxides (NOx).
- Greenhouse gas (GHG) emissions, primarily carbon dioxide (CO_2), contribute to climate change. EPA and the National Highway Traffic Safety Administration recently adopted GHG emissions regulations for heavy-duty engines and vehicles.

EPA established the following emission limits for heavy-duty engines made after 2009:

- PM—0.01 grams per brake horsepower-hour (g/bhp-hr)
- NMHC—0.14 g/bhp-hr
- NOx—0.20 g/bhp-hr.

EPA also regulates the sulfur content in on-highway diesel fuel. Ultra-low sulfur diesel fuel was considered a "technology enabler," paving the way for advanced, sulfur-intolerant exhaust emission control technologies, such as catalytic diesel particulate filters and NOx catalysts.

PM and NMHC are well controlled by these catalytic filtering systems. NOx may be reduced by the use of exhaust gas recirculation (EGR) and selective catalytic reduction (SCR).

EGR is a NOx emissions reduction process that recirculates a portion of an engine's exhaust gas back to the engine combustion chambers. This recirculated gas dilutes the mixture of gases and helps reduce the combustion temperature. Because NOx form primarily at high temperature, the lower combustion temperature results in reduced NOx output.

SCR involves injecting a urea-based solution known as diesel exhaust fluid (DEF) into a stream of exhaust gas. The urea is combined with engine exhaust in the presence of a catalyst to convert smog-forming NOx into nitrogen and water vapor.

Conversion emission standards for heavy-duty vehicles manufactured before 2010 remain the same as the standards applicable in the year of engine manufacture. Conversion companies must obtain a certificate of compliance for each model year engine family being converted.

Multiple-Stage Construction of Medium- and Heavy-Duty Vehicles

Vocational heavy-duty trucks are typically manufactured in multiple stages: An incomplete vehicle or chassis cab is progressively upfitted with equipment according to the specific tasks the vehicle will perform and is then certified as a complete vehicle by a final-stage manufacturer before delivery to the end user. The incomplete vehicle may be modified, or "manufactured," by multiple intermediate-stage manufacturers before going to the final-stage manufacturer or may only require a single manufacturing operation by the final-stage manufacturer. The "manufacturing" process performed on the incomplete vehicle by intermediate- or final-stage manufacturers depends on the end-use application and the associated specialized equipment requirements, which may include installing equipment, such as refuse packing bodies, paint-striping systems, snow plows, or aerial platform boom truck bodies, or modifying the chassis (e.g., moving or adding axles or modifying the length of the frame).

Because of the vast array of possible final vehicle configurations, and to increase overall flexibility of the manufacturing process, alternative-fuel storage systems (e.g., for CNG, LNG, or propane) may be installed by intermediate- or final-stage manufacturers rather than by the incomplete chassis manufacturer. This may add steps to the manufacturing process but also allows greater design flexibility. This installation is typically transparent to the vehicle purchaser and is consistent with the multistage manufacturing approach utilized within the market segment. The intermediate- and final-stage manufacturers are typically coordinated by the vehicle dealer, final-stage manufacturer, or equipment manufacturer, depending on the established purchasing arrangements, which may be unique for each type of vehicle purchased or for each fleet.

Step-by-Step Manufacturing Process

Four major systems must be integrated into each heavy-duty vocational truck:

- Chassis
- Engine
- Fuel system
- Specialty equipment.

Chassis

For alternative fuel applications, chassis configurations are selected based on end-use requirements in the same way that conventionally fueled chassis cabs are, except in cases where additional frame length or increased gross vehicle weight rating (GVWR) is required to accommodate a larger and/or heavier fuel storage system. Chassis are available in conventional and cab-over-axle configurations based on manufacturers' decisions about the best design that will accommodate alternative fuel engines. Cab configurations and frame length are important considerations in chassis selection.

Engine

Chassis are available with OEM alternative-fuel engines, or with gasoline or diesel engines converted to operate on an alternative fuel by installing an emissions-certified conversion system. Alternative fuel engines that run on CNG, LNG, or propane can be dedicated to operate full time on the alternative fuel; bi-fuel to run on either the alternative fuel or gasoline; or dual-fuel to run on the alternative fuel and use diesel for ignition assist. Advanced hybrid vehicles combine gasoline or diesel engine operation with battery power that reduces petroleum consumption.

Fuel System

CNG, LNG, and propane are stored in cylinders onboard a vehicle. Cylinders are heavier than gasoline or diesel tanks and less flexible in shape—making them more challenging to package on the vehicle. This can result in less volume or weight capacity for these vehicles when compared to a vehicle with a conventional fuel system. Thoughtful design considerations can compensate for these drawbacks.

Specialty equipment manufacturers have recognized the challenges associated with packaging alternative fuel storage systems with sufficient storage capacity and have developed products that seamlessly integrate the alternative fuel system into their product or body structure. In other cases, utility body manufacturers have integrated the fuel system into the body equipment to minimize any reductions in fuel storage capacity.

Specialty Equipment Upfitting

The final step is upfitting the chassis with the equipment necessary for the desired application, e.g., refuse packer, paint-striping rig, shuttle bus, or beverage delivery hauler.

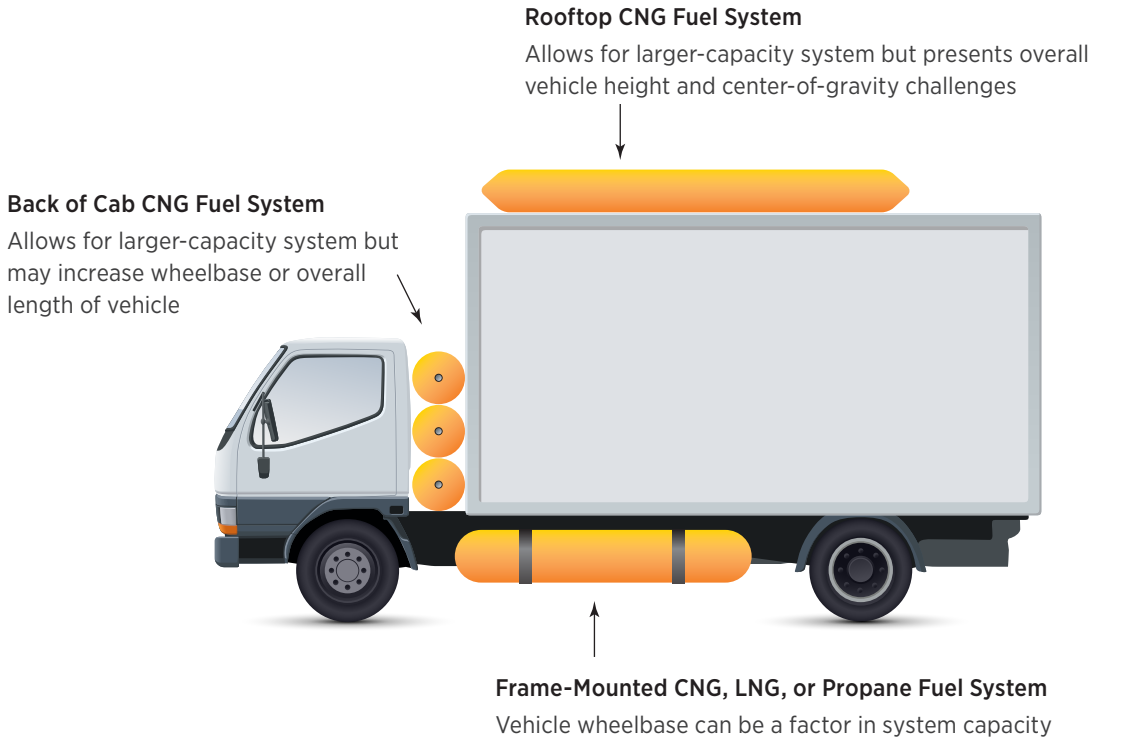


Illustration from iStock 9723056, NREL

Chassis Selection

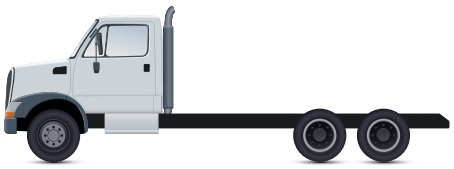
A cab chassis is a body style and type of vehicle construction often found in medium-duty commercial vehicles. Instead of a pre-assembled flatbed, cargo container, or other equipment, the customer buys the vehicle with just chassis rails and a cab. This allows the upfitter to assemble any desired aftermarket equipment, such as fire apparatus, an ambulance, beverage truck, or other application-specific equipment.

Chassis selection for use with alternative fuels must account for the weight of required fuel tanks or battery packs. The additional weight may reduce cargo space or cargo capacity. In the case of a truck plus a trailer or trailers, the gross vehicle weight as well as the overall length of the vehicle must be within the limits specified by state regulations where the truck or tractor-trailer is to be operated.

Cab Chassis Types

Conventional Cab

The long hood design allows for the power plant to be located ahead or mostly ahead of the cowl. It may be used on a two- or three-axle chassis. It is best suited to long-distance highway operation.



Conventional Cab with Set-Back Axle

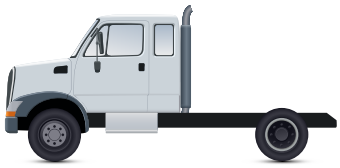
This is similar to a conventional cab but features a set-back front axle for better maneuverability in traffic and better weight transfer to the front axle. It may be used on a two- or three-axle chassis.

Tilt Cab or Cab Over Engine

This chassis features an extremely short front-bumper-to-back-of-cab dimension. The engine is positioned beneath the cab with a provision for tilting the cab forward on a pivot to provide access to the engine. It permits better weight transfer to the front axle and better maneuverability compared to conventional cab-forward designs. It is usually used on a three-axle chassis; it can also be used on a two-axle chassis.

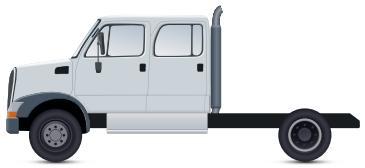
Extended Cab

An extended cab has additional storage space behind the front seat for cargo and/or passengers and is longer than a conventional cab. It is usually used with a two-axle chassis.



Crew Cab

A crew cab features four doors and six-passenger seating. It is used with a two-axle chassis.



Source: NTEA

Illustrations from iStock 9723056, NREL

Chassis Manufacturers

Manufacturer	Models	Applications	Website
Autocar LLC	Xpeditor ACX, Xpeditor E3, Xpert	Heavy-duty refuse hauler or vocational truck, medium-duty truck	*www.autocartruck.com*
Blue Bird Corp.	All-American Rear Engine, Vision	School bus	*www.blue-bird.com*
Crane Carrier	LDT2, LET2, COE2	Medium-duty vocational truck, heavy-duty refuse hauler	*www.cranecarrier.com*
Ford Motor Co.	E-150/250/350/450, F-250/350/450/550/650/750, F-53/59	Shuttle bus, vocational truck	*www.fleet.ford.com/showroom/environmental_vehicles*
Freightliner Custom Chassis	MT-45, MT-55	Heavy-duty truck, vocational truck	*http://freightlinerchassis.com*
Freightliner Trucks	Business Class M2 106, Plug-In Walk-In Van	Hybrid vocational truck, bus, walk-in van	*www.freightlinertrucks.com*
General Motors	Chevrolet/GMC 4500 Cutaway	Van, vocational truck	*www.gmfleet.com*
International	Durastar, Terrastar, WorkStar	Medium-duty and heavy-duty vocational truck, refuse hauler, over-road tractor	*www.internationaltrucks.com*
Kenworth	T270, T370, T440, T470H, T660, T800, W900	Medium-duty vocational truck, heavy-duty hauling, concrete mixer	*www.kenworth.com/2100_vir.asp*
Mack Trucks	TerraPro Cabover, TerraPro Low Entry	Heavy-duty refuse hauler, vocational truck	*www.macktrucks.com/#/home*
Peterbilt	320, 330 HE, 337 HE, 348 HE, 365, 367, 382, 384, 386, 388	Medium-duty vocational truck, heavy-duty refuse hauler, concrete mixer	*www.peterbilt.com/index.aspx*
Smith Electric Vehicles	Newton Cab Chassis	Medium-duty vocational applications, shuttle bus, school bus	*www.smithelectric.com*

Alternative Fuel Engines, Motors, Fuel Cells, and Microturbines

Natural Gas Engines

Current-production natural gas engines are designed to operate solely on natural gas (dedicated), on either natural gas or gasoline (bi-fuel), or on a combination of natural gas and diesel fuel (dual-fuel). Dedicated and bi-fuel natural gas engines are spark-ignited, and dual-fuel engines utilize a minimal amount of diesel for pilot ignition in compression-ignition combustion. Natural gas is stored onboard the vehicle as either CNG or LNG. CNG is more common and has a longer history of use in vehicles, but LNG is popular in heavy-duty applications for which maximum fuel capacity and extended driving range are required. CNG is stored at pressures of 3,000–3,600 pounds per square inch (psi) in specially designed and constructed cylinders onboard the vehicle. LNG is cooled to a cryogenic temperature of approximately -260°F and stored as a liquid onboard the vehicle in double-wall, vacuum-insulated storage tanks.

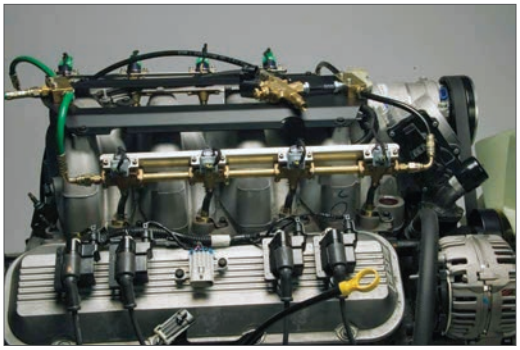
Cummins Westport ISL G natural gas engine.
Photo from Cummins Westoport

Natural gas is a clean-burning alternative fuel and offers a number of advantages to users. It is colorless, non-corrosive, and odorless, though an odorant is commonly added to aid in leak detection. A switch from conventional diesel vehicles to natural gas vehicles (NGVs) has the potential to result in lower levels of emissions, including NOx and PM. Additionally, natural gas is generally less expensive than diesel or gasoline.

Propane Engines

Propane—also known as liquefied petroleum gas, LPG, or autogas—is a byproduct of crude oil refining and natural gas processing. Propane is a gas at room temperature and is stored onboard a vehicle as a liquid in a tank pressurized to about 150 psi.

Propane vehicles operate much like gasoline vehicles with spark-ignited engines. There are two types of propane fuel-injection systems available: vapor and liquid injection. In a vapor-injection system, liquid propane is controlled by a regulator or vaporizer, which converts the liquid to vapor, which is then drawn into the combustion chamber. In a liquid-injection system, fuel is delivered to the combustion chamber in liquid form.



CleanFUEL USA liquid propane injection system.
Photo from CleanFUEL USA

Because propane is a low-carbon, clean-burning fuel, a switch to propane has the potential to result in reductions of hydrocarbon, carbon monoxide (CO), NOx, and GHG emissions. In addition, propane is nontoxic, so it isn't harmful to soil or water when spilled or leaked.

All-Electric

An all-electric vehicle, sometimes called a battery-electric vehicle, is one that uses a battery pack to power an electric motor as its sole source of propulsion. The battery pack is charged by being plugged in. Batteries may be, but are not limited to, lead acid, nickel metal hydride, or lithium ion. Electric vehicles powered by rechargeable batteries offer a number of benefits, including reduced noise from the lack of an internal combustion engine (ICE), no gear changes, and fewer moving parts. The vehicles themselves generate no NOx, SOx, PM, CO_2, or CO emissions, though emissions are associated with the majority of electricity production in the United States.

Fuel Cells

Fuel cells produce electricity through a chemical reaction—typically between hydrogen and oxygen—with water and heat as byproducts. In a fuel cell vehicle, the electricity is used to power an electric motor that drives the vehicle's wheels. In addition to producing zero tailpipe emissions, hydrogen fuel cells are attractive for transportation applications for two main reasons: First, hydrogen can be produced from various sustainable and domestic resources; second, fuel cells are more efficient than conventional ICEs in utilizing the chemical energy contained in the fuel. Fuel cells convert roughly 50% of the hydrogen's energy into electricity.

Ballard FCvelocity fuel cell.
Photo from Ballard Power Systems

Hydrogen storage is one of the major barriers to fuel cell use in vehicles. Hydrogen has a low energy density. To give fuel cell vehicles an adequate driving range, hydrogen must be stored onboard the vehicles in a gaseous state under very high pressure (e.g., 700 bar), as a cryogenic liquid, or in another medium (e.g., methanol, ethanol, or natural gas) from which hydrogen is extracted through an onboard reformer. Another option is materials-based storage, including chemical hydrides or adsorbents. Several manufacturers are testing hydrogen vehicles and have demonstrated models with the driving ranges required for the consumer market.

Microturbines

A microturbine acts as an auxiliary power unit (APU) in series hybrid vehicles, in applications such as transit buses or trucks. The microturbine charges the batteries, which in turn power the electric motor that drives the wheels of the vehicle. The microturbine can be fueled with natural gas, waste methane, biodiesel, diesel, or propane. A microturbine expands a vehicle's range while providing added power for auxiliary loads (e.g., air conditioning and heat), thus reducing engine wear, fuel use, and emissions.

Microturbine. *Photo from Capstone Turbine Corp.*

Engines Certified for Biodiesel

Biodiesel or biodiesel blends are used by heavy-duty vehicle operators to reduce petroleum consumption and pollutant emissions. Biodiesel is a domestic, renewable fuel for diesel engines, which must meet the specifications of ASTM D6751. Biodiesel is produced from vegetable oils, animal fats, or biomass conversion, but it is not the same as raw vegetable oil.

B5 (5% biodiesel, 95% petroleum diesel) can be used in any diesel vehicle. Engine manufacturers may certify their engines for use with B20 (20% biodiesel, 80% petroleum diesel). Significant reductions of PM, CO, and hydrocarbon emissions can be achieved with B20 blends. Minor impacts in peak torque and fuel economy are related to the lower energy density of biodiesel fuels, but thermal efficiency is unchanged. The National Renewable Energy Laboratory's Biodiesel Handling and Use Guide is a source of more information about biodiesel as a transportation fuel. Find it using the AFDC publications search (*afdc.energy.gov/afdc/progs/pubs.php*).

Conversions

Some fleets may decide to convert their existing conventional vehicles to operate on an alternative fuel. Conversions of heavy-duty vehicles involve replacing or rebuilding the engine and adding appropriate fuel storage systems.

Alternative fuel engines and powertrains are now being packaged by their manufacturers to be a direct replacement for their diesel counterparts. A Cummins Westport CNG engine, for example, is configured to mount in a chassis just like a diesel engine does, and an Allison parallel hybrid transmission can mount in the same space as a standard automatic transmission.

Companies that perform alternative fuel conversions must possess EPA or CARB certification that is specific to the make, model, and model year of the engine in question. The lists of systems certified by EPA and/or CARB are updated regularly. Visit *epa.gov/otaq/consumer/fuels/altfuels/altfuels.htm* and *arb.ca.gov/msprog/aftermkt/altfuel/altfuel.htm* for the most current lists of certified systems for vehicles of all model years.

Engine, Motor, Fuel Cell, and Microturbine Manufacturers

Manufacturer	Model	Fuel/Technology	Website
Ballard Power Systems	FCvelocity HD6 Fuel Cell Module, FCvelocity-9SSL Fuel Cell Stack	Hydrogen	*www.ballard.com*
Capstone Turbine Corp.	C30, C65, C200, C600, C800, C1000 MicroTurbine	Natural gas, propane	*www.microturbine.com*
Clean Air Power	MaxxForce 13 dual-fuel engine	Natural gas	*www.cleanairpower.com*
Cummins Westport	ISL G 8.9L, ISX12 G	Natural gas	*www.cumminswestport.com*
DesignLine International	ECOSaver IV	Microturbine	*www.designlinecorporation.com*
Doosan Infracore America Corp.	GL11K	Natural gas	*http://usa.doosaninfracore.co.kr/Product/CE_engine.aspx*
Enova Systems	Zero Emissions Drive System (120kW)	Electricity	*www.enovasystems.com*
Ford Motor Co.	4.6L FFV, 5.4L FFV, 6.8L EFI FFV engines	E85	*www.fleet.ford.com*
General Motors	6.0L Vortec	Natural gas, propane	*www.gmfleet.com*
Greenkraft	Greenkraft 8.8L	Natural gas	*http://greenkraftinc.com/index.html*
Hydrogenics	HyPM HD; HD 30; HD 90; HD 180 Fuel Cell Power Modules	Hydrogen	*www.hydrogenics.com*
UTC Power	PureMotion Model 120 Fuel Cell	Hydrogen	*www.utcpower.com*
Westport Innovations	GX 15L Engine, HD 400, HD 450, HD 475	Natural gas	*www.westport.com*

Medium- and Heavy-Duty Vehicle Conversion Companies

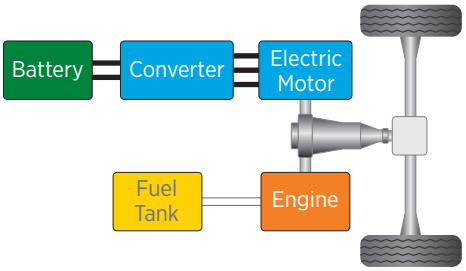
Conversion System Manufacturer	Fuel/Technology	Vehicle OEMs	Website
A-1 Alternative Fuel Systems	Natural gas, propane	Ford	*www.a1autoelectric.com*
American Alternative Fuel	Propane	Ford, General Motors	*www.aafuel.com*
American Power Group	Natural gas	Caterpillar, Detroit Diesel	*www.americanpowergroupinc.com*
BAF Technologies	Natural gas	Ford	*www.baftechnologies.com*
Bi-Phase Technologies	Propane	Ford, General Motors	*www.bi-phase.com*
CleanFUEL USA	Propane	General Motors	*www.cleanfuelusa.com*
Go Natural	Natural gas	Ford	*www.gonaturalcng.com/index.php*
Greenkraft	Natural gas	General Motors	*http://greenkraftinc.com/alternativeFuelKits.html*
IMPCO Technologies	Natural gas, propane	Ford, General Motors	*www.impcoautomotive.com*
Landi Renzo	Natural gas, propane	Ford, General Motors, Isuzu	*www.landiusa.com*
Lightning Hybrids	Hybrid electric	Most existing vehicles, model year 2008 and newer	*http://lightninghybrids.com*
NatGasCar	Natural gas	Chrysler	*www.natgascar.com*
Odyne/DUECO	Electricity	Medium- and heavy-duty vocational vehicles	*www.odyne.com*
Quantum Technologies	Electricity, hybrid electric, hydrogen, natural gas, propane	Various, including Ford and General Motors, as well as custom military vehicles	*www.qtww.com*
Roush CleanTech	Propane	Ford	*www.ROUSHcleantech.com*
TransEco Energy	Natural gas	Ford	*www.transecoenergy.com/index.htm*
Venchurs	Natural gas	Ford	*www.venchurscng.com*
World CNG	Natural gas	Chrysler, Ford, General Motors, Isuzu	*www.worldcng.com*

Hybrid Propulsion Systems by Design

Hybrid vehicles rely on two or more sources to produce and deliver power, combined with an onboard rechargeable energy storage system. In hybrid electric vehicles, these two power sources are (1) a conventional ICE and (2) an electric motor combined with a battery pack. Hydraulic hybrids employ (1) a conventional ICE and (2) a hydraulic pump/motor combined with a hydraulic energy storage system or accumulator. The efficiency of hybrids can be further increased through use of advanced technologies such as regenerative braking, which captures and stores energy that would otherwise be lost during braking.

Hybrid configurations are very attractive for numerous medium- and heavy-duty applications, including stop-and-start delivery vans and trucks, refuse collection, transit buses, utility bucket trucks, and warehouse tractors. Each of these applications involves frequent engine stops and starts, extended idling, and frequent braking.

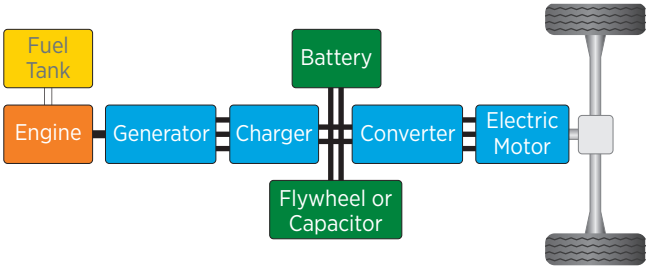
Parallel Hybrid System



Parallel hybrid systems have both an ICE and an electric motor connected directly to the transmission. Most designs combine a large electrical generator and a motor into one unit, replacing both the conventional starter motor and the alternator. To store energy, a hybrid uses a large battery pack with a higher voltage than the traditional automotive 12-volt battery.

Parallel hybrids can be further categorized depending on how balanced the two systems are in providing motive power. In some cases, the ICE is the dominant system (the electric motor turns on only when a boost or supplemental power for acceleration is needed). Other parallel hybrids can run with just the electric system operating.

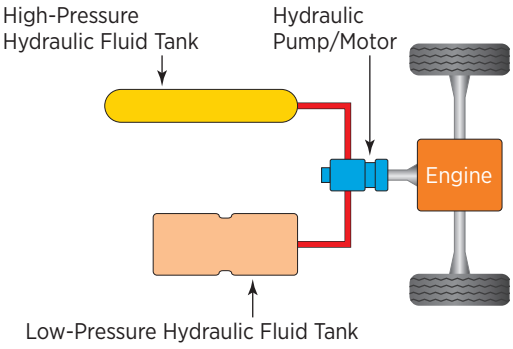
Series Hybrid System



In series or serial hybrids, the ICE drives an electric generator instead of directly driving the wheels. The generator can either charge the batteries or power an electric motor that propels the vehicle. When large amounts of power are required, the motor draws electricity from both the batteries and the generator. Series hybrids can also be fitted with an ultracapacitor or a flywheel to store regenerative braking energy, which can improve efficiency by minimizing charge depletion of the battery.

Because a series hybrid lacks a mechanical link between the ICE and the wheels, the engine can run at a constant and efficient rate, even as the vehicle changes speed.

Parallel Hydraulic Hybrid System (Launch Assist)

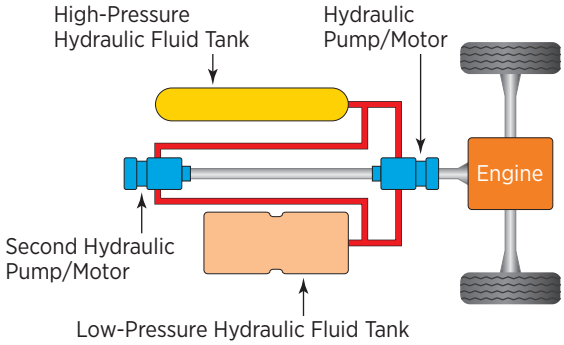


A hydraulic launch assist (HLA) system uses a hydraulic pump and motor and hydraulic storage tanks to supplement the conventional vehicle powertrain. During braking, the vehicle's kinetic energy drives the pump/motor as a pump, transferring hydraulic fluid from the low-pressure reservoir to a high-pressure accumulator. The fluid compresses nitrogen gas in the accumulator and pressurizes the system. Regenerative braking captures about 70% of the kinetic energy produced during braking. During acceleration, fluid in the high-pressure accumulator is metered out to drive the pump/motor as a motor. The system propels the vehicle by transmitting torque to the driveshaft.

Series Hydraulic Hybrid System

In a series hydraulic hybrid system, the conventional transmission and driveline are replaced by the hydraulic hybrid powertrain, and energy is transferred from the engine to the drive wheels through fluid power. The vehicle uses hydraulic pump/motors and hydraulic storage tanks to recover and store energy, similar to the way in which hybrid electric vehicles employ electric motors and batteries. The system is suited to vehicles that operate in stop-and-go duty cycles, including heavy-duty refuse hauling.

The engine operates at its "sweet spot" of fuel efficiency, facilitated by the continuously variable transmission functionality of the series hydraulic hybrid system and by regenerative braking.



Hybrid Propulsion Systems by Fuel

Diesel Hybrids

Diesel electric hybrids are powered by both a diesel ICE and an electric motor. The diesel engine powers the vehicle and generates electricity for the electric motor. The electric motor derives its power from an alternator or generator that is coupled with an energy storage device, such as a set of batteries or ultracapacitors.

Medium- and heavy-duty vehicles that stop and start often are well suited for this technology, which captures regenerative braking energy to power the electric motor. The efficient operation of hybrid vehicles results in lower tailpipe emissions by running on electricity part of the time and thereby reducing fuel use.

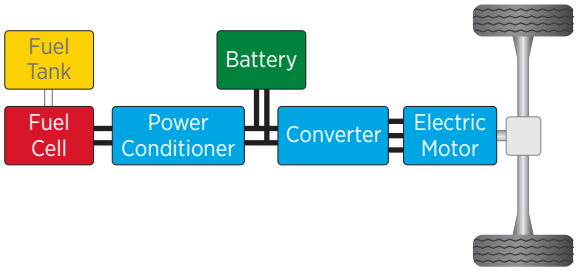
CNG Hybrids

A CNG hybrid electric system features a CNG-powered ICE, an electric motor/generator, inverters, and a battery pack. The electric motor draws energy from the battery pack or other energy storage device, such as ultracapacitors.

Because natural gas is mostly methane, NGVs have much lower NMHC emissions than gasoline vehicles do. And because the vehicle's fuel system is closed, there are no evaporative emissions, and refueling emissions are negligible. Cold-start emissions from NGVs are also low, because cold-start enrichment is not required; this reduces both volatile organic compound and CO emissions.

Fuel Cell Hybrids

Fuel cell hybrids operate much like other hybrid electric vehicles but with fuel cells producing electricity that charges the batteries, and a motor that converts electricity from the batteries into mechanical energy that drives the wheels.



System illustrations by NREL

Hybrid Propulsion System Manufacturers			
Manufacturer	**Model**	**Type**	**Website**
Allison Transmission	Allison H 40 EP	2-mode split parallel	*www.allisontransmission.com*
Allison Transmission	Allison H 50 EP	2-mode split parallel	*www.allisontransmission.com*
BAE Systems	HybriDrive Propulsion System	Series, parallel	*www.baesystems.com/ProductsServices/bae_prod_eis_hybridrive.html*
DesignLine International	ECOSaver IV	Series	*www.designlinecorporation.com*
Eaton	Eaton Hybrid Drive System	Parallel	*www.eaton.com*
Eaton	Eaton Hybrid HLA	Parallel	*www.eaton.com*
Eaton	Eaton Parallel Hybrid with Power Take-Off	Parallel	*www.eaton.com*
Enova Systems	Post Transmission Parallel Hybrid Electric Drive (90kW, 120kW, 170kW, 240kW Drive Systems)	Parallel	*www.enovasystems.com*
Lightning Hybrids	Hydraulic Hybrid	Parallel	*http://lightninghybrids.com*
Odyne	Odyne Plug-in hybrid with electric PTO	Parallel	*www.odyne.com*
Parker Hannifin Corp.	RunWise Advanced Hydraulic Hybrid	Series	*www.parker.com*
Quantum Technologies	F-Drive	Gasoline plug-in hybrid (150kW parallel system)	*www.qtww.com*
Quantum Technologies	M-Drive	Diesel (JP8) series hybrid system with 8-mile EV range	*www.qtww.com*
Quantum Technologies	Q-Drive	Gasoline plug-in hybrid (300kW series system)	*www.qtww.com*
Quantum Technologies	Quiet-Drive	50kW EV drive system	*www.qtww.com*
Voith	DIWAhybrid	Parallel	*www.usa.voithturbo.com*

Medium- and Heavy-Duty Vehicles by Application

School Bus

Photo from Blue Bird Corp.

Manufacturer: Blue Bird Corp.

- Manufacturer Website: *www.blue-bird.com*
- Model: All American Rear Engine
- Application: School bus
- Fuel Type(s): CNG
- Maximum Seating: 84
- Power Source(s): Cummins Westport ISL G 8.9L

No Photo Available

Manufacturer: Blue Bird Corp.

- Manufacturer Website: *www.blue-bird.com*
- Model: Micro Bird G5
- Application: School bus
- Fuel Type(s): Propane
- Maximum Seating: 30
- Power Source(s): Ford 6.8L V-10
  - Roush CleanTech liquid propane fuel system

Photo from Blue Bird Corp.

Manufacturer: Blue Bird Corp.

- Manufacturer Website: *www.blue-bird.com*
- Model: Vision
- Application: School bus
- Fuel Type(s): Propane
- Maximum Seating: 77
- Power Source(s): Ford 6.8L V-10
  - Roush CleanTech liquid propane fuel system

Photo from Collins Bus Corp.

Manufacturer: Collins Bus Corp.

- Manufacturer Website: *www.collinsbuscorp.com*
- Model: NexBus Propane
- Application: School bus
- Fuel Type(s): Propane
- Maximum Seating: 30
- Power Source(s): GM 6.0L V-8
  - CleanFUEL USA liquid propane injection (LPI) system

Photo from Thomas Built Buses

Manufacturer: Thomas Built Buses

- Manufacturer Website: *www.thomasbus.com*
- Model: Minotour Propane
- Application: School bus
- Fuel Type(s): Propane
- Maximum Seating: 30
- Power Source(s): GM 6.0L V-8
  - CleanFUEL USA liquid propane injection (LPI) system

Photo from Thomas Built Buses

Manufacturer: Thomas Built Buses

- Manufacturer Website: *www.thomasbus.com*
- Model: Saf-T-Liner C2e Hybrid
- Application: School bus
- Fuel Type(s): Diesel electric hybrid
- Maximum Seating: 81
- Power Source(s): Cummins ISB 6.7L
- Hybrid System(s): Eaton parallel hybrid-drive system

No Photo Available

Manufacturer: Thomas Built Buses

- Manufacturer Website: *www.thomasbus.com*
- Model: Saf-T-Liner C2 Propane
- Application: School bus
- Fuel Type(s): Propane
- Maximum Seating: 81
- Power Source(s): GM 8.0L V-8
  - CleanFUEL USA liquid propane injection (LPI) system

Photo from Thomas Built Buses

Manufacturer: Thomas Built Buses

- Manufacturer Website: *www.thomasbus.com*
- Model: Saf-T-Liner HDX CNG
- Application: School bus
- Fuel Type(s): CNG
- Maximum Seating: 90
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Trans Tech

Manufacturer: Trans Tech

- Manufacturer Website: *www.transtechbus.com*
- Model: ETrans
- Application: School bus
- Fuel Type(s): Electricity
- Maximum Seating: 52
- Power Source(s): 120kW induction motor with lithium-ion batteries

Shuttle Bus

No Photo Available

Manufacturer: Champion Bus Inc.

- Manufacturer Website: *www.championbus.com*
- Model: CTS – Front Engine
- Application: Shuttle bus
- Fuel Type(s): CNG
- Maximum Seating: 32
- Power Source(s): Cummins Westport ISL G 8.9L

No Photo Available

Manufacturer: Champion Bus Inc.

- Manufacturer Website: *www.championbus.com*
- Model: Defender
- Application: Shuttle bus
- Fuel Type(s): Gasoline electric hybrid
- Maximum Seating: 32
- Additional Description: Available with an optional hybrid chassis

No Photo Available

Manufacturer: Ebus

- Manufacturer Website: *www.ebus.com*
- Model: EBUS22FC
- Application: Shuttle bus
- Fuel Type(s): Hydrogen fuel cell hybrid, gasoline electric hybrid
- Maximum Seating: 22
- Power Source(s): Ballard Power Systems FCvelocity-HD6 fuel cell
  Ballard Power Systems PEM Mark 9 SSL fuel cell
  Capstone Turbine C30 (30kW) MicroTurbine
- Additional Description: Ebus fuel cell buses are plug-in electric buses with the fuel cell and batteries configured electrically in series. The bus can operate on battery-only power for part of the day. The Ebus hybrid electric bus uses an ultra-low emission micro-turbine as an onboard hybrid generator.

Photo from Goshen Coach

Manufacturer: Goshen Coach

- Manufacturer Website: *www.goshencoach.com*
- Model: GCII/G-Force
- Application: Shuttle bus
- Fuel Type(s): CNG, propane
- Maximum Seating: 33
- Power Source(s): Ford 6.8L V-10
  GM 6.0L V-8
- Additional Description: May be converted to use CNG or propane

Photo from IC Bus

Manufacturer: IC Bus

- Manufacturer Website: *www.icbus.com*
- Model: HC Series Hybrid
- Application: Shuttle bus
- Fuel Type(s): Diesel electric hybrid
- Maximum Seating: 45
- Power Source(s): Navistar MaxxForce DT
- Hybrid System(s): Eaton Fuller hybrid drive

No Photo Available

Manufacturer: StarTrans Bus

- Manufacturer Website: *www.startransbus.com*
- Model: President
- Application: Shuttle bus
- Fuel Type(s): CNG, propane
- Maximum Seating: 35
- Additional Description: May be converted to use CNG or propane

No Photo Available

Manufacturer: StarTrans Bus

- Manufacturer Website: *www.startransbus.com*
- Model: Senator
- Application: Shuttle bus
- Fuel Type(s): CNG
- Maximum Seating: 17
- Power Source(s): Ford 5.4L V-8
  Ford 6.8L V-10
- Additional Description: May be converted to use CNG

Photo from Turtle Top

Manufacturer: Turtle Top

- Manufacturer Website: *www.turtletop.com*
- Model: Odyssey
- Application: Shuttle bus
- Fuel Type(s): CNG, propane
- Maximum Seating: 24
- Power Source(s): GM 6.0L V-8
  Ford 6.8L V-10
- Additional Description: Available as a Chevrolet G4500 or Ford E-450 chassis; may be converted to use CNG or propane

Photo from Turtle Top

Manufacturer: Turtle Top

- Manufacturer Website: *www.turtletop.com*
- Model: Odyssey XL
- Application: Shuttle bus
- Fuel Type(s): CNG, propane
- Maximum Seating: 41
- Power Source(s): Ford 6.8L V-10
- Additional Description: Available as a Ford F-550 chassis; may be converted to use CNG or propane

Photo from Turtle Top

Manufacturer: Turtle Top

- Manufacturer Website: *www.turtletop.com*
- Model: Odyssey XLT
- Application: Shuttle bus
- Fuel Type(s): CNG, diesel electric hybrid
- Maximum Seating: 50
- Hybrid System(s): FM2 Eaton hybrid system
- Additional Description: Available as a Freightliner M2 106 chassis; may be converted to use CNG

Photo from Turtle Top

Manufacturer: Turtle Top

- Manufacturer Website: *www.turtletop.com*
- Model: Terra Transport
- Application: Shuttle bus
- Fuel Type(s): CNG, propane
- Maximum Seating: 15
- Power Source(s): GM 6.0L V-8
- Additional Description: Available as a Chevrolet Express or GMC Savana 3500 chassis; may be converted to use CNG or propane

Photo from Turtle Top

Manufacturer: Turtle Top

- Manufacturer Website: *www.turtletop.com*
- Model: Van Terra
- Application: Shuttle bus
- Fuel Type(s): CNG, propane
- Maximum Seating: 15
- Power Source(s): Ford 6.8L V-8
- Additional Description: Available as a Ford E-350 chassis; may be converted to use CNG or propane

Transit Bus

Photo from DesignLine Corp.

Manufacturer: DesignLine Corp.

- Manufacturer Website: *www.designlinecorporation.com*
- Model: EcoSaver IV
- Application: Transit bus
- Fuel Type(s): CNG electric hybrid, diesel electric hybrid
- Maximum Seating: 40
- Power Source(s): Capstone C30 MicroTurbine (30kW)
  Capstone C65 MicroTurbine (65kW)
- Hybrid System(s): DesignLine EcoSaver IV
- Additional Description: Uses a small APU and can operate on battery-only power, with regenerative braking

Photo from DesignLine Corp.

Manufacturer: DesignLine Corp.

- Manufacturer Website: *www.designlinecorporation.com*
- Model: Eco-Smart 1
- Application: Transit bus
- Fuel Type(s): Electricity
- Maximum Seating: 28
- Power Source(s): Two 120kW Bosch Rexroth induction motors
- Additional Description: Operates up to 120 miles on a single charge under high-density, stop-and-go, urban transit

Photo from ElDorado National

Manufacturer: ElDorado National

- Manufacturer Website: *www.econline.com*
- Model: Axess
- Application: Transit bus
- Fuel Type(s): CNG, LNG, diesel electric hybrid, hydrogen fuel cell
- Maximum Seating: 41
- Power Source(s): Cummins ISL 8.9L
  Cummins Westport ISL G 8.9L
  Ballard Power Systems FCvelocity-HD6 fuel cell
- Hybrid System(s): Allison H 40 EP
  BAE Systems HybriDrive

Photo from ElDorado National

Manufacturer: ElDorado National

- Manufacturer Website: *www.econline.com*
- Model: EZ Rider II BRT
- Application: Transit bus
- Fuel Type(s): CNG, LNG, diesel electric hybrid
- Maximum Seating: 33
- Power Source(s): Cummins ISB 6.7L
  Cummins Westport ISL G 8.9L
- Hybrid System(s): Allison H 40 EP

Photo from ElDorado National

Manufacturer: ElDorado National

- Manufacturer Website: *www.econline.com*
- Model: XHF
- Application: Transit bus
- Fuel Type(s): CNG, LNG
- Maximum Seating: 39
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Gillig

Manufacturer: Gillig

- Manufacturer Website: *www.gillig.com*
- Model: Diesel Electric Hybrid Bus and CNG Bus
- Application: Transit bus
- Fuel Type(s): CNG, diesel electric hybrid
- Maximum Seating: 40
- Power Source(s): Cummins ISL 8.9L
  Cummins Westport ISL G 8.9L
- Hybrid System(s): Allison H 40 EP

Photo from Motor Coach Industries

Manufacturer: Motor Coach Industries

- Manufacturer Website: *www.mcicoach.com*
- Model: D4500 CT Hybrid Commuter Coach
- Application: Transit bus
- Fuel Type(s): CNG, diesel electric hybrid
- Maximum Seating: 57
- Power Source(s): Cummins ISL 8.9L
  Cummins Westport ISL G 8.9L
- Hybrid System(s): Allison H 50 EP

Photo from New Flyer

Manufacturer: New Flyer

- Manufacturer Website: *www.newflyer.com*
- Model: Xcelsior
- Application: Transit bus, trolley
- Fuel Type(s): CNG, LNG, diesel electric hybrid, hydrogen fuel cell hybrid, electricity
- Maximum Seating: Varies
- Power Source(s): Ballard Power Systems FCvelocity-HD6 fuel cell
  Cummins ISL 8.9L
  Cummins Westport ISL G 8.9L
- Hybrid System(s): Allison H 40 EP
  BAE Systems HybriDrive

Photo from North American Bus Industries

Manufacturer: North American Bus Industries

- Manufacturer Website: *www.nabusind.com*
- Model: 31LFW/35LFW/40LFW
- Application: Transit bus
- Fuel Type(s): CNG, diesel electric hybrid
- Maximum Seating: 40
- Power Source(s): Cummins ISL 8.9L
  Cummins Westport ISL G 8.9L
- Hybrid System(s): Allison H 40 EP
  Allison H 50 EP
- Additional Description: Available in 31-, 35-, and 40-foot models with a low-floor body

Photo from North American Bus Industries

Manufacturer: North American Bus Industries

- Manufacturer Website: *www.nabusind.com*
- Model: 42BRT
- Application: Transit bus
- Fuel Type(s): CNG, LNG, diesel electric hybrid
- Maximum Seating: 43
- Power Source(s): Cummins ISL 8.9L
  Cummins Westport ISL G 8.9L
- Hybrid System(s): Allison H 40 EP
  Allison H 50 EP

Photo from North American Bus Industries

Manufacturer: North American Bus Industries

- Manufacturer Website: *www.nabusind.com*
- Model: 60BRT
- Application: Transit bus
- Fuel Type(s): CNG, LNG, diesel electric hybrid
- Maximum Seating: 43
- Power Source(s): Cummins ISL 8.9L
  Cummins Westport ISL G 8.9L
- Hybrid System(s): Allison H 40 EP

Photo from North American Bus Industries

Manufacturer: North American Bus Industries

- Manufacturer Website: *www.nabusind.com*
- Model: CompoBus
- Application: Transit bus
- Fuel Type(s): CNG, diesel electric hybrid
- Maximum Seating: 47
- Power Source(s): Cummins ISL 8.9L
  Cummins Westport ISL G 8.9L
- Hybrid System(s): Allison H 40 EP

Photo from Nova Bus

Manufacturer: Nova Bus

- Manufacturer Website: *www.novabus.com*
- Model: LFS Artic HEV
- Application: Transit bus
- Fuel Type(s): Diesel electric hybrid
- Maximum Seating: 62
- Power Source(s): Cummins ISB 6.7L
- Hybrid System(s): Allison H 40 EP

Photo from Nova Bus

Manufacturer: Nova Bus

- Manufacturer Website: *www.novabus.com*
- Model: LFS HEV
- Application: Transit bus
- Fuel Type(s): Diesel electric hybrid
- Maximum Seating: 41
- Power Source(s): Cummins ISB 6.7L
- Hybrid System(s): Allison H 40 EP

Photo from Nova Bus

Manufacturer: Nova Bus

- Manufacturer Website: *www.novabus.com*
- Model: LFX
- Application: Transit bus
- Fuel Type(s): Diesel electric hybrid
- Maximum Seating: Varies
- Power Source(s): Cummins ISB 6.7L
  Cummins ISL 8.9L
- Hybrid System(s): Allison H 40 EP
  Allison H 50 EP
- Additional Description: Engine-drive combination depends on length

Photo from Proterra

Manufacturer: Proterra

- Manufacturer Website: *www.proterra.com*
- Model: EcoRide BE35
- Application: Heavy-duty transit bus
- Fuel Type(s): Electricity
- Maximum Seating: 35
- Power Source(s): UQM PowerPhase 150kW permanent magnet motor

Photo from Van Hool

Manufacturer: Van Hool

- Manufacturer Website: *www.vanhool.be*
- Model: A300L Fuel Cell
- Application: Transit bus
- Fuel Type(s): Hydrogen fuel cell
- Maximum Seating: 28
- Power Source(s): Ballard Power Systems hydrogen fuel cell
  UTC fuel cell

Refuse Truck

No Photo Available

Manufacturer: Autocar

- Manufacturer Website: *www.autocartruck.com*
- Model: E3 Hybrid
- Application: Refuse truck
- Fuel Type(s): Diesel electric hybrid
- Power Source(s): Cummins ISL 8.9L
- Hybrid System(s): Parker RunWise

Photo from Heil Environmental

Manufacturer: Heil Environmental

- Manufacturer Website: *www.heil.com*
- Model: DuraPack Python
- Application: Refuse truck
- Fuel Type(s): CNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Heil Environmental

Manufacturer: Heil Environmental

- Manufacturer Website: *www.heil.com*
- Model: Front Loader
- Application: Refuse truck
- Fuel Type(s): CNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Heil Environmental

Manufacturer: Heil Environmental

- Manufacturer Website: *www.heil.com*
- Model: Rapid Rail
- Application: Refuse truck
- Fuel Type(s): CNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Heil Environmental

Manufacturer: Heil Environmental

- Manufacturer Website: *www.heil.com*
- Model: Rear Loader
- Application: Refuse truck
- Fuel Type(s): CNG
- Power Source(s): Cummins Westport ISL G 8.9L

No Photo Available

Manufacturer: Heil Environmental

- Manufacturer Website: *www.heil.com*
- Model: Roll-Off Hoist
- Application: Refuse truck
- Fuel Type(s): CNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Mack Trucks

Manufacturer: Mack Trucks

- Manufacturer Website: *www.macktrucks.com*
- Model: LEU TerraPro Low Entry
- Application: Refuse truck
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Mack Trucks

Manufacturer: Mack Trucks

- Manufacturer Website: *www.macktrucks.com*
- Model: MRU TerraPro Cabover
- Application: Refuse truck
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from McNeilus

Manufacturer: McNeilus

- Manufacturer Website: *www.mcneiluscompanies.com*
- Model: Front Loader (Contender, Atlantic, Low-Profile)
- Application: Refuse truck
- Fuel Type(s): CNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from McNeilus

Manufacturer: McNeilus

- Manufacturer Website: *www.mcneiluscompanies.com*
- Model: Rear Loader (Std, HD, XC, Tag, MS, Metro-Pak)
- Application: Refuse truck
- Fuel Type(s): CNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from McNeilus

Manufacturer: McNeilus

- Manufacturer Website: *www.mcneiluscompanies.com*
- Model: Side Loader (ZR, AutoReach)
- Application: Refuse truck
- Fuel Type(s): CNG
- Power Source(s): Cummins Westport ISL G 8.9L

No Photo Available

Manufacturer: Peterbilt

- Manufacturer Website: *www.peterbilt.com*
- Model: Model 320 G
- Application: Refuse truck
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Peterbilt

Manufacturer: Peterbilt

- Manufacturer Website: *www.peterbilt.com*
- Model: Model 320 HLA
- Application: Refuse truck
- Fuel Type(s): Diesel hydraulic hybrid
- Power Source(s): Cummins ISL 8.9L
- Hybrid System(s): Eaton hydraulic launch assist (HLA)

Tractor

No Photo Available

Manufacturer: Balqon

- Manufacturer Website: *www.balqon.com*
- Model: Nautilus XE-20
- Application: Terminal tractor
- Fuel Type(s): Electricity
- Power Source(s): 200-hp, 230V AC induction motor with 215kWh, 312V lithium-ion batteries

Photo from Balqon

Manufacturer: Balqon

- Manufacturer Website: *www.balqon.com*
- Model: Nautilus XE-30
- Application: Terminal tractor
- Fuel Type(s): Electricity
- Power Source(s): 200-hp, 230V AC induction motor with 215kWh, 600V lithium-ion batteries

No Photo Available

Manufacturer: Capacity Trucks

- Manufacturer Website: *www.capacitytrucks.com*
- Model: HETT
- Application: Terminal tractor
- Fuel Type(s): Electricity

Photo from Capacity Trucks

Manufacturer: Capacity Trucks

- Manufacturer Website: *www.capacitytrucks.com*
- Model: TJ5000/TJ7000
- Application: Terminal tractor
- Fuel Type(s): Propane
- Power Source(s): Ford 6.8L V-10
  GM 8.0L V-8

Photo from Capacity Trucks

Manufacturer: Capacity Trucks

- Manufacturer Website: *www.capacitytrucks.com*
- Model: TJ9000
- Application: Terminal tractor
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Cargotec

Manufacturer: Cargotec

- Manufacturer Website: *www.cargotec.com*
- Model: Ottawa 4x2
- Application: Terminal tractor
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Freightliner

Manufacturer: Freightliner

- Manufacturer Website: *www.freightlinertrucks.com*
- Model: Business Class M2 112
- Application: Tractor
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Freightliner

Manufacturer: Freightliner

- Manufacturer Website: *www.freightlinertrucks.com*
- Model: Cascadia 113 NG
- Application: Tractor
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISX12 G

No Photo Available

Manufacturer: Freightliner

- Manufacturer Website: *www.freightlinertrucks.com*
- Model: M2 106 Hybrid
- Application: Tractor
- Fuel Type(s): Diesel Electric Hybrid
- Power Source(s): Cummins ISB 6.7L
- Hybrid System(s): Eaton parallel electric hybrid

Photo from Kenworth

Manufacturer: Kenworth

- Manufacturer Website: *www.kenworth.com*
- Model: T270/T370 Diesel Electric Tractor
- Application: Tractor
- Fuel Type(s): Diesel electric hybrid
- Power Source(s): Paccar PX-6 6.7L
- Hybrid System(s): Eaton parallel electric hybrid

Photo from Kenworth

Manufacturer: Kenworth

- Manufacturer Website: *www.kenworth.com*
- Model: T440 Tractor
- Application: Tractor
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISL G 8.9L
- Additional Description: Can be a Class 7 or a Class 8 truck

Photo from Kenworth

Manufacturer: Kenworth

- Manufacturer Website: *www.kenworth.com*
- Model: T470 Tractor
- Application: Tractor
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISL G 8.9L
- Additional Description: Can be a Class 7 or a Class 8 truck

Photo from Kenworth

Manufacturer: Kenworth

- Manufacturer Website: *www.kenworth.com*
- Model: T660 Tractor
- Application: Tractor
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISX12 G
- Additional Description: A Class 8 heavy-duty truck designed for on-highway purposes, such as general freight and regional haul

Photo from Kenworth

Manufacturer: Kenworth

- Manufacturer Website: *www.kenworth.com*
- Model: T800 Short Hood
- Application: Tractor
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISX12 G
- Additional Description: Can be configured to accomplish a variety of heavy-duty vocational applications

Photo from Kenworth

Manufacturer: Kenworth

- Manufacturer Website: *www.kenworth.com*
- Model: T800 Tractor
- Application: Tractor
- Fuel Type(s): LNG
- Power Source(s): Westport GX
- Additional Description: Designed for heavy-duty port, freight, and vocational applications with an operating range of 300 to 500 miles

No Photo Available

Manufacturer: Peterbilt

- Manufacturer Website: *www.peterbilt.com*
- Model: 337
- Application: Tractor
- Fuel Type(s): Diesel electric hybrid
- Power Source(s): Paccar PX-6 6.7L
- Hybrid System(s): Eaton parallel electric hybrid

Photo from Peterbilt

Manufacturer: Peterbilt

- Manufacturer Website: *www.peterbilt.com*
- Model: 365
- Application: Tractor
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Peterbilt

Manufacturer: Peterbilt

- Manufacturer Website: *www.peterbilt.com*
- Model: 367/386/388
- Application: Tractor
- Fuel Type(s): LNG
- Power Source(s): Westport GX
- Additional Description: Designed for regional- and long-haul applications

Photo from Peterbilt

Manufacturer: Peterbilt

- Manufacturer Website: *www.peterbilt.com*
- Model: 382
- Application: Tractor
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISL G 8.9L
- Additional Description: A heavy-duty truck designed for regional-haul applications

Photo from Peterbilt

Manufacturer: Peterbilt

- Manufacturer Website: *www.peterbilt.com*
- Model: 384
- Application: Tractor
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Peterbilt

Manufacturer: Peterbilt

- Manufacturer Website: *www.peterbilt.com*
- Model: 386HE
- Application: Tractor
- Fuel Type(s): Diesel electric hybrid
- Power Source(s): Paccar MX-13
- Hybrid System(s): Eaton diesel electric hybrid

Photo from Vision Motor Corp.

Manufacturer: Vision Motor Corp.

- Manufacturer Website: *www.visionmotorcorp.com*
- Model: Tyrano
- Application: Tractor
- Fuel Type(s): Hydrogen fuel cell hybrid
- Power Source(s): 65kW hydrogen fuel cell
- Hybrid System(s): Eaton hybrid
- Additional Description: A Class 8, zero-emission tractor that combines the acceleration of a battery-powered electric vehicle with the extended range of a hydrogen fuel cell vehicle

No Photo Available

Manufacturer: Vision Motor Corp.

- Manufacturer Website: *www.visionmotorcorp.com*
- Model: ZETT Zero-Emission Terminal Tractor
- Application: Terminal tractor
- Fuel Type(s): Hydrogen fuel cell hybrid
- Power Source(s): 16.5kW hydrogen fuel cell
- Hybrid System(s): Vision electric hydrogen hybrid
- Additional Description: Developed in conjunction with Capacity Trucks

Photo from Volvo

Manufacturer: Volvo

- Manufacturer Website: *www.volvotrucks.com*
- Model: VNL Daycab
- Application: Tractor
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISX12 G
  Volvo D12-LNG

Photo from Volvo

Manufacturer: Volvo

- Manufacturer Website: *www.volvotrucks.com*
- Model: VNM Daycab
- Application: Tractor
- Fuel Type(s): CNG
- Power Source(s): Cummins Westport ISL G 8.9L

Van

Photo from Boulder Electric Vehicle

Manufacturer: Boulder Electric Vehicle

- Manufacturer Website: *www.boulderev.com*
- Model: DV-500 Delivery Truck
- Application: Step van
- Fuel Type(s): Electricity
- Power Source(s): AC brushless induction motor with lithium-ion batteries
- Additional Description: Has an estimated range of up to 120 miles per eight-hour charge

Photo from Electric Vehicles International

Manufacturer: Electric Vehicles International

- Manufacturer Website: *www.evi-usa.com*
- Model: WI EVI
- Application: Step van
- Fuel Type(s): Electricity
- Power Source(s): 120kW, AC permanent magnet electric motor with 99kWh lithium-ion batteries manufactured by Valence Technologies

Photo from Enova

Manufacturer: Enova Systems

- Manufacturer Website: *www.enovasystems.com*
- Model: Ze Step Van
- Application: Step van
- Fuel Type(s): Electricity
- Additional Description: Built on a custom Freightliner MT-45 chassis

Photo from Ford Motor Co.

Manufacturer: Ford Motor Co.

- Manufacturer Website: *www.ford.com/commercial-trucks*
- Model: E-Series Cargo Van/Wagon
- Application: Cargo van
- Fuel Type(s): CNG, propane
- Power Source(s): Ford 5.4L V-8
  Ford 6.8L V-10
- Additional Description: CNG and propane models are available from contract converters for models equipped with Ford's gaseous fuel engine prep package.

Photo from Ford Motor Co.

Manufacturer: Ford Motor Co.

- Manufacturer Website: *www.ford.com/commercial-trucks*
- Model: Transit Connect
- Application: Cargo van
- Fuel Type(s): CNG, propane
- Power Source(s): Ford 2.0L I-4
- Additional Description: CNG and propane models are available from contract converters for models equipped with Ford's gaseous fuel engine prep package.


Photo from General Motors

Manufacturer: General Motors

- Manufacturer Website: *www.gmfleet.com*
- Model: Express/Savana CNG Cargo Van
- Application: Cargo van
- Fuel Type(s): CNG
- Power Source(s): GM 6.0L V-8
- Additional Description: Available with a three-tank (200-mile range) or four-tank (300-mile range) system


Photo from General Motors

Manufacturer: General Motors

- Manufacturer Website: *www.gmfleet.com*
- Model: Express/Savana Cutaway Van
- Application: Cutaway van
- Fuel Type(s): Propane
- Power Source(s): GM 6.0L V-8
- Additional Description: Available with a three-tank (200-mile range) or four-tank (400-mile range) system


Photo from Smith Electric Vehicles

Manufacturer: Smith Electric Vehicles

- Manufacturer Website: *www.smithelectric.com*
- Model: Newton Step Van
- Application: Step van
- Fuel Type(s): Electricity
- Power Source(s): 134kW brushless permanent magnet electric motor with lithium-ion batteries
- Additional Description: Batteries available in 40kWh, 60kWh, 80kWh, 100kWh, and 120kWh capacities

Vocational Truck

Photo from Balqon

Manufacturer: Balqon

- Manufacturer Website: *www.balqon.com*
- Model: Mule M150
- Application: Vocational truck
- Fuel Type(s): Electricity
- Power Source(s): 200-hp AC induction motor with lithium-ion batteries

Photo from Electric Vehicles International

Manufacturer: Electric Vehicles International

- Manufacturer Website: *www.evi-usa.com*
- Model: EVI-MD
- Application: Vocational truck
- Fuel Type(s): Electricity
- Power Source(s): 260-hp AC permanent magnet motor with lithium-ion batteries

Photo from Elgin

Manufacturer: Elgin

- Manufacturer Website: *www.elginsweeper.com*
- Model: Broom Bear/Crosswind/Eagle/Pelican
- Application: Street sweeper
- Fuel Type(s): CNG, LNG, propane
- Power Source(s): Cummins Westport ISL G 8.9L
  Ford 2.5L propane
  GM 3.0L CNG

Photo from Ford Motor Co.

Manufacturer: Ford Motor Co.

- Manufacturer Website: *www.ford.com/commercial-trucks*
- Model: E-Series Cutaway and Stripped Chassis
- Application: Vocational truck
- Fuel Type(s): CNG, E85 flex fuel, propane
- Power Source(s): Ford 5.4L V-8
  Ford 6.8L V-10

No Photo Available

Manufacturer: Freightliner

- Manufacturer Website: *www.freightlinertrucks.com*
- Model: Business Class M2 106 Hybrid
- Application: Vocational truck
- Fuel Type(s): Diesel electric hybrid
- Power Source(s): Cummins ISB 6.7L
- Hybrid System(s): Eaton parallel electric hybrid

Photo from Freightliner

Manufacturer: Freightliner

- Manufacturer Website: *www.freightlinertrucks.com*
- Model: Business Class M2 112, 114SD, Cascadia
- Application: Vocational truck
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISX12 G
  Cummins Westport ISL G 8.9L

Photo from Greenkraft

Manufacturer: Greenkraft

- Manufacturer Website: *www.greenkraftinc.com*
- Model: 1061
- Application: Vocational truck
- Fuel Type(s): CNG, LNG, propane
- Power Source(s): GM 6.0L

Photo from Hino

Manufacturer: Hino

- Manufacturer Website: *www.hino.com*
- Model: 195n
- Application: Vocational truck
- Fuel Type(s): Diesel electric hybrid
- Power Source(s): Hino 5L
- Hybrid System(s): Hino hybrid drive

Photo from Kenworth

Manufacturer: Kenworth

- Manufacturer Website: *www.kenworth.com*
- Model: T270
- Application: Vocational truck
- Fuel Type(s): Diesel electric hybrid
- Power Source(s): Paccar PX-6 6.7L
- Hybrid System(s): Eaton hybrid drive

Photo from Kenworth

Manufacturer: Kenworth

- Manufacturer Website: *www.kenworth.com*
- Model: T370
- Application: Vocational truck
- Fuel Type(s): Diesel electric hybrid
- Power Source(s): Paccar PX-6 6.7L
- Hybrid System(s): Eaton hybrid drive

Photo from Kenworth

Manufacturer: Kenworth

- Manufacturer Website: *www.kenworth.com*
- Model: W900S
- Application: Vocational truck
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISX12 G

Photo from McNeilus

Manufacturer: McNeilus

- Manufacturer Website: *www.mcneilusconcrete.com*
- Model: CNG Cement Mixer
- Application: Vocational truck
- Fuel Type(s): CNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Peterbilt

Manufacturer: Peterbilt

- Manufacturer Website: *www.peterbilt.com*
- Model: 330 Hybrid
- Application: Vocational truck
- Fuel Type(s): Diesel electric hybrid
- Power Source(s): Paccar PX-6 6.7L
- Hybrid System(s): Eaton hybrid drive

Photo from Peterbilt

Manufacturer: Peterbilt

- Manufacturer Website: *www.peterbilt.com*
- Model: 337/338 Hybrid
- Application: Vocational truck
- Fuel Type(s): Diesel electric hybrid
- Power Source(s): Paccar PX-6 6.7L
- Hybrid System(s): Eaton hybrid drive

Photo from Peterbilt

Manufacturer: Peterbilt

- Manufacturer Website: *www.peterbilt.com*
- Model: 365
- Application: Vocational truck
- Fuel Type(s): CNG, LNG
- Power Source(s): Cummins Westport ISL G 8.9L

Photo from Smith Electric Vehicles

Manufacturer: Smith Electric Vehicles

- Manufacturer Website: *www.smithelectric.com*
- Model: Newton
- Application: Vocational truck
- Fuel Type(s): Electricity
- Power Source(s): 134kW brushless permanent magnet electric motor with lithium-ion batteries

No Photo Available

Manufacturer: TYMCO

- Manufacturer Website: *www.tymco.com*
- Model: 600
- Application: Street sweeper
- Fuel Type(s): CNG, propane
- Power Source(s): KEM 5.7L

Photo from ZeroTruck

Manufacturer: ZeroTruck

- Manufacturer Website: *www.zerotruck.com*
- Model: ZeroTruck
- Application: Vocational truck
- Fuel Type(s): Electricity
- Power Source(s): UQM PowerPhase 100 electric motor

Glossary

AFDC . . . . . Alternative Fuels Data Center
APU . . . . . Auxiliary power unit
B20 . . . . . A blend containing 20% biodiesel and 80% petroleum diesel fuel
BRT . . . . . Bus rapid transit
CARB . . . . . California Air Resources Board
CNG . . . . . Compressed natural gas
CO . . . . . Carbon monoxide
CO_2 . . . . . Carbon dioxide
EGR . . . . . Exhaust gas recirculation
EPA . . . . . U.S. Environmental Protection Agency
FFV . . . . . Flexible fuel vehicle
GCWR . . . . . Gross combined weight rating
GHG . . . . . Greenhouse gas
G/BHP-HR . . . . . Grams per brake horsepower-hour
GVWR . . . . . Gross vehicle weight rating
HLA . . . . . Hydraulic launch assist
ICE . . . . . Internal combustion engine
LF . . . . . Low floor
LNG . . . . . Liquefied natural gas
LPG . . . . . Liquefied petroleum gas (propane)
LPI . . . . . Liquid propane injection
NGV . . . . . Natural gas vehicle
NMHC . . . . . Non-methane hydrocarbons
NOx . . . . . Oxides of nitrogen
OEM . . . . . Original equipment manufacturer
PM . . . . . Particulate matter
SCR . . . . . Selective catalytic reduction
SOx . . . . . Sulfur oxides

Photo from Nova Bus

U.S. Department of Energy

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