COMMERCIAL VEHICLES || FORECAST

# NORTH AMERICA ON-HIGHWAY CV ENGINE OUTLOOK

REPORT VERSION PUBLISHED NOVEMBER 2019



2019 LAWRENCE R. KLEIN BLUE CHIP AWARD WINNER

Contributor to Blue Chip Economic Indicators and WSJ Economic Forecast Panel

ACT N.A. On-Highway Commercial Vehicle Engine OUTLOOK is published quarterly by Americas Commercial Transportation Research Company (ACT). 4440 Middle Road, Columbus, IN 47203. Phone: 812.379.2085, Fax: 812.378.5997, email: trucks@actresearch.net. 

# SAMPLE REPORT OVERVIEW:

Thank you for your interest in ACT Research and our work. The objective of this sample report is to share an understanding of the market, economy, and insight to analysis at the time of publication. We share this report from 2017 for market context, assessment of our forecast, its accuracy, and its methods.

# North America On-Highway Commercial Vehicle Engine OUTLOOK

The Engine OUTLOOK is a quarterly report produced in collaboration with Rhein Associates. Where ACT's N.A. Commercial Vehicle OUTLOOK monthly report drills down to forecasts by vehicle type, the Engine OUTLOOK take the top-line MD and HD forecasts from the N.A. Commercial Vehicle OUTLOOK report and breaks the market down by engine displacement. In addition to a 5-year forecast by engine displacement and captive versus independent market share, the report spends considerable time tracking the pipeline of new engine developments by OEM for medium and heavy-duty markets and by fuel-type.

Report Video - CLICK HERE

# Report Dashboard Overview:

With your subscription to the ***N.A. On-Highway CV Engine OUTLOOK***, you will gain access to our report dashboard. Below is a listing, as well as a screenshot, of this dashboard and the support material you will receive with your report.

1. PDF of Current Month Report
2. Tables including: CLICK HERE FOR SAMPLE DATA FILE
    - A. Heavy Duty Engine Breakdowns w/ Captive, Non-Captive, Tractor, Captive Share %
    - B. Medium Duty Engine Breakdowns w/ Truck, Bus, RV, Chassis, Class 5
    - C. Medium Duty Engine Fuel Type Breakdowns
    - D. GHG2 Standards, Fuel Standards, Vocational Standards
    - E. Forecast Tables
3. Graph pack complete with nearly 100 graphs covering: CLICK HERE FOR SAMPLE GRAPHS
    - A. Class 8
    - B. Classes 5-7
4. Regulatory Environment

# Report Distribution & FAQs

**When is the report published?**

The *N.A. On-Highway CV Engine OUTLOOK* is published once per quarter towards the end of each quarter.

**How many individuals in my company may access the report?**

ACT Research allows for a maximum distribution of 4 users per report. Additional access may be purchased at $60 per person, per report.

**Can the individuals with report access be changed?**

Yes, we understand that change in staff may occur. Simply call or email our team and we'll help you manage this process. There is no charge for changing users.

**How do I become aware of the release of the latest publication?**

A notice, via email, will be sent to those users on your distribution list upon the publication and availability of the *N.A. On-Highway Engine OUTLOOK*. Users can then access the report via dashboard login.

**Is support for ACT Research analyst available should questions arise?**

Yes, we highly encourage our subscribers to call or email our staff with questions or concerns. Our analysts take great pride in being accessible and are willing to answer questions as needed.

**May I utilize aspects of the report within my organization?**

Yes, but we do request that all tables, graphs, charts, or analysis cite ACT Research as the source.

**May I utilize aspects of the report for external presentations? (conferences, trade organizations, etc.)**

Yes. ACT's copyright policy requires that any external presentations utilizing ACT data be sourced and cited appropriately. Furthermore, we request that external sourcing be limited to charts and/or graphs. If you are uncertain if your presentation meets our copyright requirements, contact us at 812.379.2085 or trucks@actresearch.net to inquire.

"I would recommend ACT Research to anyone that's looking for in-depth insight into what's happening in the commercial vehicle markets. The expertise and knowledge that goes into the service they provide, there's not a better solution, in my opinion, for commercial vehicle data than ACT Research."
- Jeff Trent, Mahle

# TABLE OF CONTENTS

# HIGHLIGHTS

***Click paragraphs to zoom to more details***

## OEMS: ENGINE TRENDS & ALT FUEL UPDATES

- Compared to emission controls on MY 2010 US diesel trucks, today's compact aftertreatment systems are 40% lighter, 60% smaller, and substantially less expensive.
- Several vocational engine families have demonstrated the capability of achieving NOx emissions 50-75% below today's standards.
- A wide variety of technology options can be deployed on HD engines and vehicles to reduce engine-out NOx, while improving fuel economy to reduce the total cost of ownership.
- Cummins will stop producing the 5.0L turbocharged V8, rated at 310 horsepower and 555 lb-ft of torque.
- Concern is increasing about future supply shortages of key materials needed for electric vehicle batteries.
- Canada's Minister of Natural Resources announced a $4.6-million investment for building 92 EV fast chargers in its coast-to-coast network.

## REGULATORY ENVIRONMENT

- Oregon senators voted 16-11 in favor of a bill regulating diesel trucks in the Portland metro area.
- BP released its annual Statistical Review of World Energy, showing that the global economic growth experienced in 2018 fueled a strong increase in energy consumption, which resulted in a corresponding increase of $CO_2$ emissions.
- The EPA is proposing an advanced biofuel volume requirement for 2020 of 5.04 billion gallons.

## MARKET ANALYSIS - FORECASTS

### Heavy-Duty Vehicle (Class 8) Engines

- Following the current cycle peak in 2019, at 345,000 units, NA Class 8 production is expected to fall substantially in 2020.
- In 2024, a major reduction is projected as higher cost, more complex emission trucks are introduced in California and other CARB-compliant states.
- Engines over 10L are expected to account for more than 85% of the Class 8 production between 2020 and 2024.
- By 2024, nearly 61% of tractors are forecast to have engines under 14L.
- In 2018, under 10L production in Class 8 trucks and tractors totaled just over 41,000 units, with 2019 forecast to be similar. Production is expected to drop in 2020, before recovering through 2023.
- This year the captive share of Class 8 production is forecast at just over 61%, restricted by limited availability of some OEM engines.
- As well as engines, Class 8 OEMs are vertically integrating other components into their trucks and tractors.
- Cummins L9 is the engine of choice for most Class 8 trucks and tractors under 10L. New competition will impact Cummins' volume.

### Medium-Duty Vehicle (Classes 5-7) Engines

- 2018 North American Classes 5-7 production totaled 272,700 units, while the 2019 through 2024 average annual volume is forecast at 267,200 units.
- Classes 6-7 production grew quicker than Class 5 from 2016 to 2019. The age of Classes 6-7 vehicles is older than Class 5, and the recent higher level of production refelects replacement of older vehicles.
- In 2017, medium duty gasoline penetration was 16.1% and it increased to 16.9% in 2018.
- Gasoline engines had a 25% penetration in Class 5 use in 2018 and although a reduction is forecast for 2019, gasoline penetration is expected to increase.
- Classes 6-7 production was 176,000 in 2018, with stability expected through 2024. The forecast for annual average Classes 6-7 production from 2019 to 2024 is also 176,000 units.
- The forecast for gasoline penetration holds close to 10% through 2024 in Classes 6-7.
- Classes 6-7 trucks are forecast to have some reduction in engine size through 2024, principally with increased use of engines below 6L.

### Alternative Power

- Production of natural gas-powered trucks peaked in 2014, in response to high diesel fuel pricing, but declined as diesel prices fell.
- Natural gas' advantage to dramatically reduce emissions compared with diesel trucks is important in markets like California.

## ENGINE TRENDS

### TECHNOLOGY FEASIBILITY OF LOW $NO_X$ STANDARDS FOR HD DIESEL TRUCKS

The Manufacturers of Emission Controls Association (MECA) released a report, *Technology Feasibility for Model Year 2024 Heavy-Duty Diesel Vehicles in Meeting Lower NOx Standards*, that provides an assessment of market-ready technologies being commercialized by suppliers of emission control and efficiency components for heavy duty diesel vehicles to meet lower intermediate standards for NOx by 2024, as a transition to final low NOx standards in 2027. The report presents test results and emission models from fully aged aftertreatment systems installed on heavy duty on-road engines, offering several compliance paths that are achievable by model year 2024, without significant changes to today's engines or aftertreatment systems.

(http://www.meca.org/resources/MECA_MY_2024_HD_Low_NOx_Report_061019.pdf)

"Both the U.S. EPA and the California ARB (CARB) have announced rulemakings focused on strengthening the current heavy-duty emission standards. Getting to ultra-low NOx and greenhouse gas emission levels will require a systems approach of advanced aftertreatment technologies, efficient engines, and clean fuels," said MECA's Executive Director, Rasto Brezny.

The conclusions in this paper can be summarized as follows:

1. Compared to emission controls on MY 2010 US diesel trucks, today's compact aftertreatment systems are 40% lighter, 60% smaller, and substantially less expensive.

Manufacturers continue to optimize diesel emission controls, such as DOC (diesel oxidation catalyst), DPF and SCR, in order to promote uniform catalyst coating, improve NOx conversion efficiency, reduce back pressure on the engine, and reduce thermal mass. New substrates are designed with thinner walls or higher porosity, which allows the coating of better catalysts without sacrificing durability.

This has resulted in higher catalyst loading per volume of substrate and led to downsizing of systems from those available in 2010. Furthermore, catalyst development has produced higher activity catalysts that can provide higher NOx conversion with lower catalyst loading. While the cost of new heavy duty trucks has increased at approximately 1% per year, the cost of emission controls has come down, representing a lower percentage of the cost of a new truck. These advances have brought higher compliance margins and lower certification levels, while still meeting GHG standards. Advanced catalysts and substrates combined with better engine and urea dosing calibration can be readily employed to meet tighter NOx limits in 2024, without any significant changes to today's system design. Based on a survey of MECA's members, we estimate the cost of emission controls on a future ultra-low NOx truck to be similar to the cost of emission controls on a MY 2010 truck.

2. Several vocational engine families have demonstrated the capability of achieving NOx emissions 50-75% below today's standards, while also meeting future heavy duty greenhouse gas limits for vocational engines.

Since 2010, setting stringent emission targets for both $CO_2$ and NOx through realistic regulations and expanding the calibrator's toolbox from the engine to the powertrain has allowed engineers to achieve simultaneous NOx reductions and engine efficiency

improvements. A review of the EPA's heavy duty certification tables (U.S. EPA, 2019) indicates that a number of diesel engine families certified since 2010 have shown the ability to achieve 0.1 g/bhp-hr and lower tailpipe NOx levels over the composite federal test procedure (FTP) certification cycle. Of those engines, several have demonstrated the ability to meet future Phase 2 GHG regulation limits for vocational engines that go into effect in 2021, 2024 and 2027. History has shown that once emission control and efficiency improving technologies were required on engines, the traditional trade-off relationship between $CO_2$ and NOx emissions at the tailpipe has been overcome and reductions of both pollutants could be achieved simultaneously.

3. A wide variety of technology options can be deployed on heavy duty engines and vehicles to reduce engine-out NOx, while improving fuel economy to reduce the total cost of ownership.

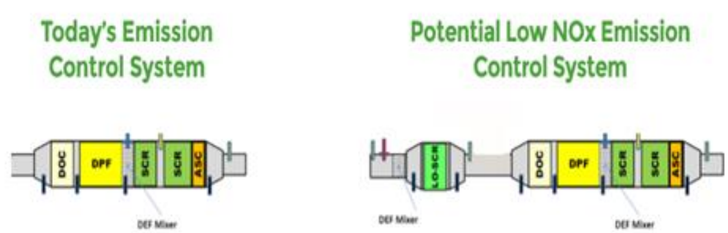
The number of on-engine technology options and strategies that OEMs may choose to deploy to meet both a 2024 NOx standard and the 2024 $CO_2$ standard has grown dramatically in recent years, as a result of the Phase 2 GHG regulation. Technologies such as cylinder deactivation (CDA), high efficiency variable geometry turbochargers with exhaust gas by-pass, and start-stop systems are only some of the available fuel saving technologies that can be implemented by 2024. Some of these strategies can be deployed on cold start to heat aftertreatment and keep it hot under low engine load operation. Other technologies that are being demonstrated on vehicles include 48V electrical architectures, combined with regenerative braking, and small batteries that can electrify auxiliary components on the engines, such as air conditioning compressors, water and oil pumps, EGR pumps, electric assist turbochargers, electrically heated catalysts, 48V motor-generators, 48V electric fans and auxiliary power units to take the load off the engines. Technologies like CDA and 48V mild hybridization can enable simultaneous NOx and $CO_2$ reduction; once implemented, these technologies will deliver fuel savings to truck owners.

4. Strategies for reducing emissions during periods of low load operation, combined with improved engine calibration and control of urea dosing, can be applied to heavy duty trucks by 2024 to enable emission control systems to achieve an FTP emission limit of 0.05 g/bhp-hr and a Low Load Cycle (LLC) limit below 0.2 g/bhp-hr.

Engine calibration and thermal management, combined with advanced catalysts and substrates, have improved to the point where a current engine plus aftertreatment system can achieve FTP emissions below 0.05 g/bhp-hr NOx, with compliance margins that OEMs need for full useful life durability. During cold-start and low-load operation, engine calibration and thermal management, including the technologies listed in (3) above, can be applied to reduce engine-out NOx emissions and provide additional heat to aftertreatment systems. Better catalysts and urea dosing systems can achieve high NOx conversion during lower temperature operation. Further compliance margins can be achieved through modest increases in catalyst volume, while still maintaining the size of future emission controls below those on model year 2010 trucks. Some engine manufacturers may choose to include a "light-off" SCR catalyst before the DOC in a twin SCR system arrangement with dual urea dosing, to gain experience with the types of strategies that may be needed for lower NOx limits in 2027. The approaches discussed for meeting 2024 NOx limits utilize improvements in thermal management and engine calibration, and existing aftertreatment system designs that employ newer high efficiency catalysts and coating strategies. Simulations of commercial catalysts over an LLC show that low temperature ammonia delivery using heated urea dosing can deliver NOx emissions below 0.2 g/bhp-hr over the LLC, representing extended low-speed operation and idling.

The new exhaust control systems could look like the image below.

The report goes on to detail the technology options that are feasible to meet both the NOx and GHG standards.




Source: SAE Paper Nos. 2017-01-0954, 2017-01-0956, and 2017-01-0958, March 2017.[3]

### CUMMINS TO END 5.0L V8 PRODUCTION

Cummins will stop producing the 5.0L turbocharged V8, rated at 310 horsepower and 555 lb-ft of torque, as reported by *The Drive*. The ISV was originally designed for use in Ram trucks, according to Nissan. The decision to drop the engine was a mutual one between Nissan and Cummins.

The 2020 Nissan Titan XD is losing its only diesel engine option and the Cummins V-8 was the only engine available in the Titan XD when launched in 2016. Diesel and overall sales have not been encouraging over the last year-and-a-half; Nissan reported a drop of 25% in July 2019 ytd sales. We estimate diesel was 75% of the Titan HD US sales in 2017, falling to 63% in 2018. Nissan was the only volume buyer.

### CUMMINS AND ISUZU ENTER INTO A POWER-SOURCE PARTNERSHIP AGREEMENT

Cummins Inc. and Isuzu Motors Limited announced another step forward in their partnership, entering into the Isuzu Cummins Powertrain Partnership agreement. The agreement formalizes a business structure for the two companies to evaluate and implement opportunities to jointly develop and bring new diesel and diesel-based powertrains to global markets. Through this Powertrain Partnership, Isuzu and Cummins share the commitment to leverage both companies' technical strengths to develop architectures for customers around the world.

Cummins and Isuzu committed to form an alliance board and to assign a team from each company to continue exploration of potential opportunities in product technology development, procurement and manufacturing.

### MAN TO INTRODUCE NEW 16.2L DIESEL ENGINE

MAN Engines, a Business Unit of MAN Truck & Bus, will be presenting its new 16.2L diesel engine for agricultural machinery for the first time at Agritechnica 2019. It is the most powerful six-cylinder in-line engine ever developed by MAN Engines for agricultural machinery and has been designed specifically for off-road applications (*at this time*), requiring the highest levels of power. It is ideally suited for heavy duty agricultural machinery with demanding load profiles, such as forage harvesters or large combine harvesters.

This engine bridges the gap in power output that currently exists between the six-cylinder in-line engine D3876, with 15.3L displacement and the V12 engine D2862 (24.2L) in MAN's current engine range. MAN will also exhibit its 9L D1556 diesel engine, the company's modular exhaust gas aftertreatment system and a special agricultural truck that demonstrates the versatility of trucks in the agricultural sector.

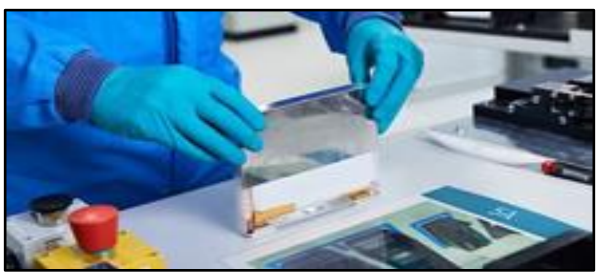
Although MAN touts the 9L and 16.2L as off-road diesels, it is an easy transition from agriculture tractor to on-highway trucks with proper emissions systems, as drives and options are compatible. Can this be the preview of two of the Traton diesels expected to be part of a new truck powertrain line-up in 2020/21?

## ALTERNATIVE FUELS

New alternatively fueled medium and heavy duty truck applications are gaining steam in market potential. A few of the latest developments are mentioned below. For details about ACT Research's *Alternative Fuels Quarterly*, click here. Details on ACT's latest EV work are available by clicking here.

### EV BATTERY SHORTAGE ANXIETY RISING

According to research done by BloombergNEF (BNEF) (https://about.bnef.com/about/), concern is about future supply shortages of key materials needed for electric vehicle batteries, as spending on new production soars, according to the developer of a $1.5B project in Australia. More than a dozen parties have now expressed interest in taking up to a 50% stake in Clean TeQ Holdings Ltd.'s Sunrise nickel-cobalt-scandium project, according to Clean TeQ CEO, Sam Riggall. Melbourne-based Clean TeQ is seeking final offers for a stake in the Sunrise project by the end of September, and will aim to complete any sale by the end of the year.



Some analysts are predicting that, by 2050, demand for metals essential to lithium-ion batteries may be in short supply.

Makers of batteries for smartphones, tablets, laptop computers, as well as electric vehicles, are competing for production materials. The shortage won't be due to a lack of raw materials, but rather a lack of mines available to meet demand. Lithium can be found across the world, but presently nearly half of the global lithium supply comes from Argentina, Bolivia, and Chile. In 2009, 26% of the world's lithium supply was used for batteries, and in 2015 that increased to 38%. Nearly 20 mining and production sites are currently planned or under construction globally, but are not expected to begin production until this year. However, a shortage of lithium may not have that great of an impact on actual costs of batteries; a 300% increase in lithium cost would only raise the price of batteries by 2%. What will be expected to impact battery prices, however, is the possibility of a shortage of cobalt; nearly 42% of global supplies are currently being used for batteries.

Cobalt is also primarily found in regions of instability. Two-thirds of the current global cobalt supply is in the Democratic Republic of Congo, where policies, corruption, and instability prevent the investment needed to match world demand. The Congo has also imposed high taxes and royalties on mining operations, driving up prices. If the price of cobalt rises 300%, the reflection in the cost of batteries would be around 13%.

It is possible to recycle both lithium and cobalt from batteries, although the process is considered expensive, inefficient, and overall not worth the effort. American Manganese, based in Vancouver, Canada, "mines" cobalt and lithium from failed batteries, costing roughly $0.30/pound. The materials then can be resold for up to $20/pound. One of the challenges the company faces is the lack of standardization in battery packaging across companies. It is estimated that up to 10% of the world's supply of lithium and cobalt could come from recycled materials by 2025. New battery technologies are also a solution like solid state batteries. As in most shortages, the supply of lithium and cobalt could dramatically increase as demand materializes.

Meanwhile, Volkswagen AG picked Sweden's Northvolt AB as a partner to start production of battery cells for electric cars, while the German and French governments have pledged funding and political support for efforts to spur a European battery manufacturing industry. Volvo Group and Samsung SDI have entered a strategic alliance to develop battery packs for Volvo Group's electric trucks. In the US, the number of battery electric models available to consumers is forecast to double by the end of 2021, according to BloombergNEF.

The scale of planned investments in electric lineups means both automakers and related industries in Europe and North America are focusing on how to secure future supplies of battery-grade nickel, and ensuring there is sufficient cobalt after the market tightens, starting around 2022. According to Bloomnberg, there's a looming shortage of nickel sulfate, the material used for battery products, with demand forecast to outstrip planned new capacity. Cobalt demand may also top global supply from about 2025.


The Volvo/Samsung SDI agreement was recently announced as the Volvo Group aims to accelerate the speed of battery development and strengthen the long-term capabilities and assets within electromobility. The alliance will cover joint development of battery packs specifically developed for Volvo Group's truck applications. Samsung SDI intends to provide battery cells and modules that will be provided for assembly in Volvo Group's manufacturing operations.

**CANADA INVESTS IN TRANSPORTATION ELECTRIFICATION**

Two major investments in transportation electrification include a comprehensive charging network and incentives to build a better battery. Canada's Ministry of Natural Resources announced a $4.6-million investment for Petro-Canada for building 92 electric vehicle (EV) fast chargers in its coast-to-coast network. The first completed station, in Stewiacke, Nova Scotia, will be part of a larger network of more than 50 Petro-Canada locations, each with two charging units on site. This is part of the Government of Canada's $182.5 million investment to build a coast-to-coast charging network for electric vehicles and support other zero- and low-carbon demonstration and deployment projects.

Over 500 fast chargers are built or planned in Canada this year, with hundreds more expected over the next two years. Through Budget 2019, a further $130 million is being invested in charging infrastructure, and a new incentive, worth up to $5,000, is available for Canadians who purchase or lease a zero-emission vehicle. Canada's climate plan includes more than 50 measures to protect the environment and leave a healthier planet for future generations, including actions to protect oceans and phase-out coal-fired electricity, as well as invest in renewables, public transit, and plastic pollution reduction efforts. Zero-emission vehicles are a key part of Canada's plan to combat climate change, while growing the economy and making life more affordable for Canadians.

Canada's Ministry of Natural Resources, also announced a new $4.5 million Impact Canada Challenge, aimed at accelerating made-in-Canada battery innovation to better position the country in the highly competitive global market. Today's $23 billion global battery industry is expected to grow to more than $90 billion over the next decade, providing major economic opportunities for Canada across the battery value chain. Central to this growth forecast is an increase in the number of electric vehicles, which are expected to exceed 130 million by 2030, as well as the growing use of storage technology to integrate renewable energy sources into the grid.

“Charging the Future” will help accelerate the most promising Canadian battery innovations from lab to market. During the 18-month challenge, five finalists will pitch their concepts to a jury of experts to win a maximum $700,000 each for the development of their battery prototype. Ultimately, the most promising battery breakthrough will be awarded a $1 million grand prize.

**CUMMINS ACQUIRES FUEL CELL COMPANY**

Continuing its determined expansion into non-traditional engine power technologies, Cummins Inc. announced a definitive agreement to acquire, through a wholly-owned subsidiary, all the issued and outstanding shares of Canadian fuel cell systems specialist Hydrogenics Corp. The transaction is expected to close in the third quarter pending necessary approvals.

Hydrogenics is a global supplier of proton exchange membrane (PEM) and alkaline hydrogen fuel cell systems for industrial processes and fueling stations. They also provide hydrogen fuel cells for electric vehicles such as urban transit buses, commercial fleets, utility vehicles and electric lift trucks, and utility-sized fuel cell installations for freestanding electrical power plants, critical power and UPS (uninterruptible power supply) systems.


Cummins began developing its electrification capabilities more than a decade ago. Cummins announced its acquisition of Silicon Valley-based Efficient Drivetrains, Inc. (EDI), which designs and produces hybrid and fully-electric power solutions for commercial markets in July 2018. In 2017, Cummins undertook strategic efforts to build capabilities across the entire range of electric storage by the acquisitions of UK-based Johnson Matthey Battery Systems and North America-based Brammo. The latter buys occurred soon after unveiling its first prototype electric truck, the Aeos. This 18,000-lbs truck features a maximum payload capacity of 44,000 lbs, with a range of 100 miles on a single charge enabled by a 140 kWh battery pack.

### LION ELECTRIC AND BOIVIN ÉVOLUTION TEAM FOR ALL-ELECTRIC WASTE HAULER

The electric garbage truck has a 249-mile (400 km) range. *Photo courtesy of Lion Electric Co.*

The Lion Electric Co. (Lion) and Boivin Évolution (BEV) unveiled a Class 8 truck with a powertrain and automated collection hopper that are 100% electric. The vehicle consists of a Lion8 chassis and the BEV all-electric automated side-loading hopper used to collect household waste, recycling, and organic material. Features of the electric truck include a range of up to 249 miles (400 km), or a full day of operation (approximately 1,200 homes) on a single charge, with no noise pollution, optimal visibility and turning radius, and zero GHG emissions, according to the company.

No hydraulic fluid is needed for pumps, pipes, and hoses, as all hopper and arm movements are battery powered. Additionally, the vehicle is expected to reduce operating costs with savings of up to 80% on total energy costs, 60% lower service costs due to a low-maintenance electric powertrain, and longer lasting brakes due to the vehicle's regenerative braking system. The vehicle is custom built in Quebec to withstand North American weather and road conditions.

### SCANIA DEBUTS URBAN UTILITY VEHICLE

Scania's new NXT concept vehicle is a modularly designed, self-driving electric vehicle that can change configurations to meet varying urban fleet requirements. The NXT features front and rear drive modules that can be fitted to a bus body, a distribution truck body, or a refuse collector. It can be a commuter bus in the morning and evening, for example, and a refuse truck overnight, and handle next-mile delivery during the day.

The 8-meter (26-ft) bus module is built as one composite unit, substantially reducing weight, Scania said. A bank of cylindrical cell batteries is placed under the floor to make use of otherwise dead space, while contributing to overall weight distribution for the vehicle. The NXT tips the scales at less than 17,600 pounds. Scania said the range of present-day batteries is estimated at 150 miles on a single charge.

Scania's approach looks similar to its Swedish cousin, Einride. The Michelin Group will support Sweden-based startup firm Einride by deploying its autonomous and all-electric T/Pod transport truck starting next year at the tire maker's production facilities in Clermont-Ferrand, France. The tire maker will roll out the Einride in two phases. First, it will go into operation transporting goods at a fenced-off Michelin site and later, it will operate on a public road to deliver freight between two Michelin facilities. The electric Einride T/Pod is capable of SAE Level 4 autonomous driving. It uses a Nvidia Drive system to process in real time the needed visual data for driverless operation. The T/Pod was designed to be driverless; there is no driver onboard and there is no cab. However, if required, the truck can be controlled remotely by human "drivers."

## NEW DIESEL TRUCK REGULATIONS FOR PORTLAND, OREGON

Oregon senators voted 16-11 in favor of a bill regulating diesel trucks in the Portland metro area. House Bill 2007 requires truck owners to replace older diesel engines with newer models by 2025. The House also passed the bill by a 44 to 15 margin. The goal is to reduce diesel pollution by requiring 2010 model year engines or newer. Those engines filter almost all the diesel particulates known to cause cancer and other respiratory diseases. The bill would help pay for engine upgrades, using about $50 million in settlement money from the Volkswagen diesel emissions cheating scandal. The legislature failed to pass similar diesel engine regulations in 2015 and 2017, but did pass a bill that directed some of the Volkswagen settlement funds toward replacing 450 older diesel school buses across the state.

Senator Michael Dembrow, D-Portland, who co-sponsored the bill, said that reducing diesel pollution will also cut greenhouse gas emissions, including the black carbon that comes from diesel engines. "The quicker we can curb that and start bringing down those particulates, not only is it good for public health but it's also necessary for the health of the planet," he said.

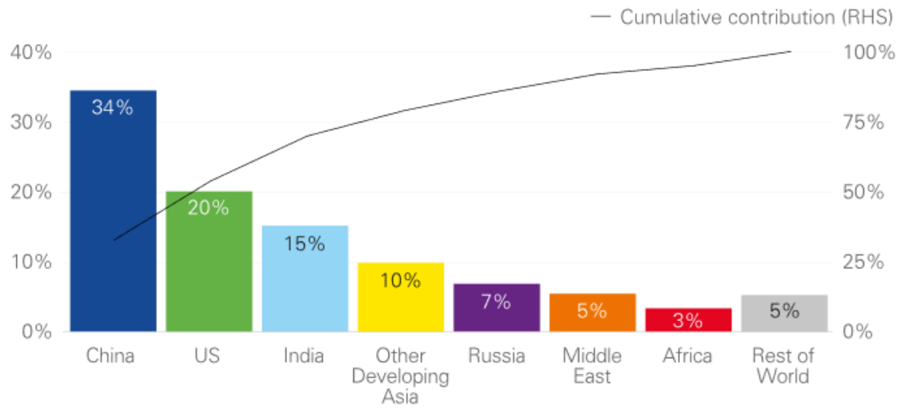
Lawmakers failed to pass a cap-and-trade bill this session to address climate change. Dembrow said that a policy of that kind would raise revenue to replace older diesel engines outside the Portland metro area.

Trucking industry opponents of the cap-and-trade bill also protested the diesel bill, but dropped their opposition after the bill was amended to affect only Portland-area trucks. Dembrow said that the problem of diesel pollution is most acute in the city. "The population density, the confluence of freeways and ports and manufacturing and construction have made Multnomah County, my county, one of the most affected by diesel pollution in the entire nation," he said. "So, we've decided we need at this point to concentrate our resources to do the most good and help the most people with public health."

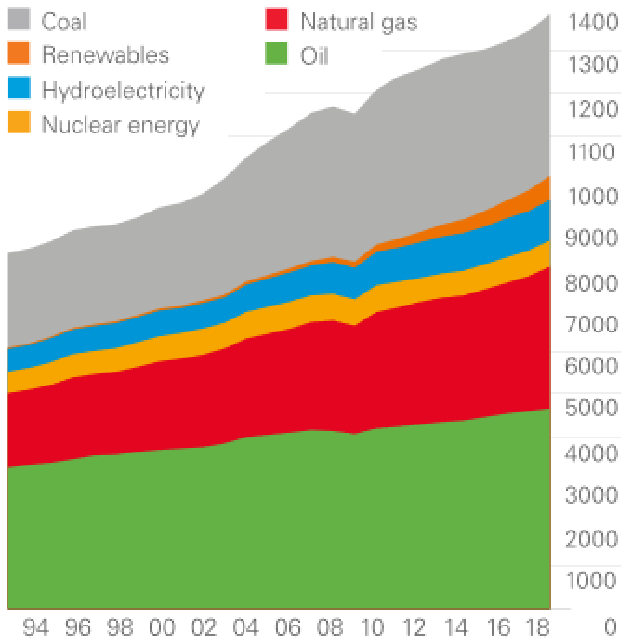
## BP STATISTICAL REVIEW: STRONG GLOBAL ENERGY DEMAND & RISING EMISSIONS

BP released its annual Statistical Review of World Energy, showing that the global economic growth experienced in 2018 fueled a strong increase in energy consumption, which resulted in a corresponding increase of $CO_2$ emissions. The highest contributors to the global primary energy growth were China (34% of the 2018 growth), followed by the United States (20%), and India (15%). US consumption expanded at its fastest rate in 30 years. Primary energy consumption increased by 2.9% in 2018. Growth was the strongest since 2010, almost doubling the 10-year average of 1.5% per year. Carbon emissions grew by 2.0%, the fastest growth for seven years.

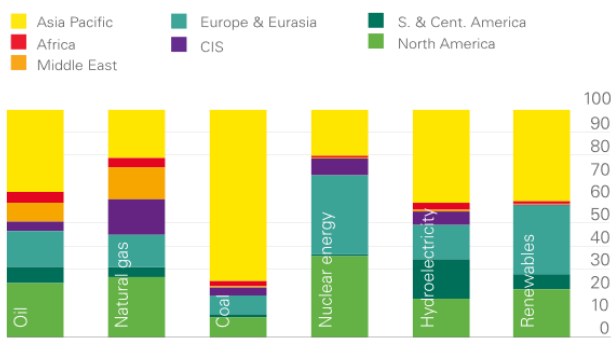
The growth for all fuels increased, but growth was particularly strong in the case of gas (168 mtoe accounting for 43% of the global increase). All fuels grew faster than their 10-year averages, apart from renewables, although renewables still accounted for the second largest increment to energy growth (71 mtoe, 18% of the global increase).



**Primary energy – world consumption (million tonnes oil equivalent)**




**Fuel consumption by region 2018 (percentage)**

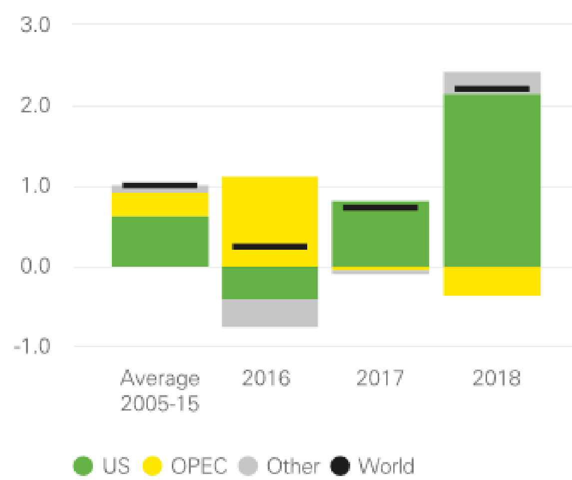



Some of the highlights from the BP Statistical Review include:

Oil:

- Oil consumption in 2018 grew by an above-average 1.4 million barrels per day (mbd) or 1.5%. In an absolute sense, the growth in demand was dominated by the developing world, with China (0.7 mbd) and India (0.3 mbd) accounting for almost two-thirds of the global increase. In the US, oil demand grew by 0.5 mbd, its largest increase in more than 10 years and in sharp contrast to the trend decline seen in the decade or so prior to the oil price crash of 2014.
- The strength in US oil demand in recent years has been concentrated in gasoline and diesel, but the increased importance of petrochemicals in driving oil demand growth was also evident in the global product breakdown, with products most closely related to petrochemicals (ethane, LPG and naphtha) accounting for around half of the overall growth in demand last year.
- Global oil production increased by 2.2 million b/d in 2018, or 2.4%, double its 10-year average growth. This expansion was heavily concentrated in the US (2.2 million b/d), a record for any country in any year. Most of this growth was due to increases in tight oil and natural gas liquids (NGLs). Elsewhere, production grew in Canada (410,000 b/d) and Saudi Arabia (390,000 b/d), while oil production declined sharply in Venezuela (-580,000 b/d) and Iran (-310,000 b/d).

**Global oil production—annual change, mbd**




Natural Gas:

- In 2018, both global consumption and production increased more than 5%, one of the strongest growth rates in either gas demand or output in 30-plus years.
- Natural gas consumption rose by 195 billion cubic meters (bcm), or 5.3%, one of the fastest rates of growth since 1984. Growth in gas consumption was driven mainly by the US (78 bcm), and maybe China, which also saw above-average growth of 17.7% (43 bcm), Russia (23 bcm), and Iran (16 bcm). The US gas

consumption increase of 78 bcm last year is broadly equivalent to the entire gas consumption of the UK.

- Global natural gas production increased by 190 bcm, or 5.2%. Almost half of this came from the US (86 bcm), which (as with oil production) recorded the largest annual growth seen by any country in history. The US production increase was driven by shale plays in Marcellus, Haynesville and Permian. Russia (34 bcm), Iran (19 bcm), and Australia (17 bcm) were the next largest contributors to growth.

Coal:

- Coal consumption increased by 1.4% in 2018, the fastest growth since 2013, driven by Asia Pacific (71 Mtoe) and particularly by India (36 Mtoe). This region now accounts for more than three quarters of global consumption, while 10 years ago it represented two thirds. The growth in coal demand was the second consecutive year of increases, following three years of falling consumption. As a result, the peak in global coal consumption, which many thought had occurred in 2013, now looks less certain.
- World coal production increased by 105 million tonnes of oil equivalent, or 3.2%, the fastest rate of growth since 2011. Production rose by 56 mtoe (3.6%) in China and 23 mtoe (6.9%) in the US. Interestingly, the increase in US production came despite a further fall in domestic consumption, with US coal producers instead increasing exports to Asia.

Nuclear Energy, Hydroelectricity, and Renewables:

- Nuclear consumption increased by 2.4% in 2018. China (10 mtoe) accounted for almost 75% of global growth, as nuclear consumption in China more than quadrupling in the last 10 years. Japan (5 mtoe) had the second largest increase. The largest declines were recorded in South Korea (-3 mtoe) and Belgium (-3 mtoe).
- World hydroelectric consumption rose by 3.1%, slightly above the 10-year average (2.8%), with China (8 mtoe) and Brazil (4 mtoe) posting the largest contributions.
- Renewable power consumption (excluding hydro but including wind, solar, geothermal, and wave power) grew by 14% in 2018, providing 9% of the world's electricity. Wind power provided 4.8% of global power, with an expansion rate of 14%. Solar provided 2.2% of global power and grew by 29% in 2018.

CLEAN ENERGY MINISTERIAL

Advancing Clean Energy Together

**NEW HYDROGEN INITIATIVE LAUNCHES**

At the 10th Clean Energy Ministerial (CEM10) meeting, a new international hydrogen partnership was announced under the leadership of the United States, Canada, Japan, the Netherlands and the European Commission, with participation of several other CEM member countries. The International Energy Agency (IEA) will coordinate efforts under this initiative. For the first time under the Clean Energy Ministerial, this effort will put the spotlight on the role that hydrogen and fuel cell technologies can play in the global clean energy transition. The new hydrogen initiative will drive international collaboration on policies, programs and projects to accelerate the commercial deployment of hydrogen and fuel cell technologies across all sectors of the economy.

Drawing on the recommendations from the Hydrogen Energy Ministerial Meeting in 2018, this cross-country collaboration will build on the successes of other global collaborations about hydrogen, such as the Hydrogen Challenge under Mission Innovation, the ongoing work through the International Partnership for Hydrogen and Fuel Cells in the Economy and global analysis carried out through the International Energy Agency (IEA). It will address barriers and identify opportunities for hydrogen in the global transformation to a clean, affordable and reliable energy sector, including global supply chains for this new energy sector. The new Hydrogen Initiative will focus on how hydrogen can contribute to cleaner energy systems, while promoting sustainability, resiliency and energy security. Initial work will focus on three different areas:

1. Helping to ensure successful deployment of hydrogen within current industrial applications,

2. Enabling deployment of hydrogen technologies in transport (freight, mass transit, light-rail, marine),
3. Exploring the role of hydrogen in meeting the energy needs of communities.

The private sector also plays an important role in this global transition, and the Hydrogen Initiative will leverage and benefit from the knowledge, expertise and early investments made by both the private and public sectors. Leading industry stakeholders and collaborative forums, such as the Hydrogen Council, will continue the work undertaken through the initiative.

### EPA PROPOSES RENEWABLE VOLUME OBLIGATIONS FOR 2020

US Environmental Protection Agency (EPA) Administrator, Andrew Wheeler, issued a proposed rule under the Renewable Fuel Standards (RFS) program that would set the minimum amount of renewable fuels that must be supplied to the market in calendar year 2020, as well as the biomass-based diesel volume standard for calendar year 2021. This puts the EPA on target to publish the final RFS Renewable Volume Obligations (RVOs) for the third consecutive year.

"Conventional" renewable fuel volumes, primarily met by corn ethanol, would be maintained at the implied 15 billion gallon target set by Congress. The EPA is proposing an advanced biofuel volume requirement for 2020 of 5.04 billion gallons, which is 0.12 billion gallons higher than the advanced biofuel volume requirement for 2019.The cellulosic biofuel volume requirement of 0.54 billion ethanol-equivalent gallons for 2020 is based on a production projection, which is 0.12 billion ethanol-equivalent gallons higher than the cellulosic biofuel volume finalized for 2019. The EPA proposes to maintain the biomass-based diesel (BBD) volume for 2021 at 2.43 billion gallons.

The table below shows the proposed and final Renewable Fuel Volume Requirements for 2019-2021.

The Clean Air Act requires the EPA to set annual RFS volumes of biofuels that must be used for transportation fuel in four categories of biofuels: total, advanced, cellulosic, and biomass-based diesel. The EPA is using the tools provided by Congress to adjust the standards below the statutory targets, based on current market realities. The EPA implements the RFS program in consultation with the US Department of Agriculture (USDA) and the US Department of Energy (DOE).

| | 2019 | 2020 Statutory Volumes | 2020 Proposed Volumes | 2021 Proposed Volumes |
|---|---|---|---|---|
| Cellulosic biofuel (billion gallons) | 0.42 | 10.50 | 0.54 | n/a |
| Biomass-based diesel (billion gallons) | 2.1 | ≥1.0 | N/A | 2.43 |
| Advanced biofuel (billion gallons) | 4.92 | 15.00 | 5.04 | n/a |
| Renewable fuel (billion gallons) | 19.92 | 30.00 | 20.04 | n/a |
| All values are ethanol-equivalent on an energy content basis, except for BBD which is biodiesel-equivalent. | | | | |

**DERA's FOURTH REPORT TO CONGRESS: DIESEL EMISSIONS REDUCTION PROGRAM**

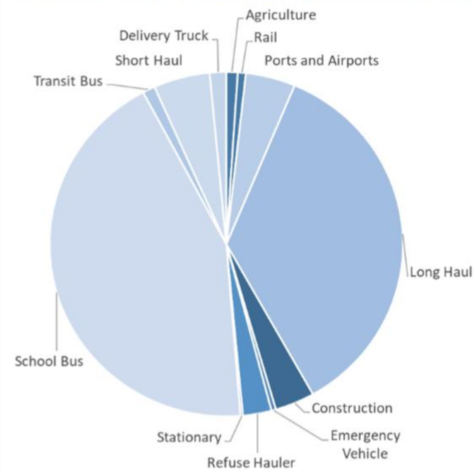
From transportation to power generation, the diesel engine is in every part of the US economy. Invented in the 1890s, it is durable and strong. With an assist to regulators, new engines coming off the manufacturing line are now sixty times cleaner than prior to the start of the EPA's emissions standards. However, nearly 10 million older diesel engines are still in use in communities across the US, emitting diesel exhaust, which can harm human health and the environment. The Diesel Emissions Reduction Act (DERA) program, authorized in 2005 and reauthorized with unanimous bipartisan support in 2010, is the only federal program addressing legacy engines as its sole mission. Cost-effective, targeted to disproportionately affected communities, and supported by American industry, the DERA program continues to evolve with market and stakeholder demands. (https://www.epa.gov/sites/production/files/2019-07/documents/420r19005.pdf)

The EPA's National Clean Diesel Campaign (NCDC), within the Office of Transportation and Air Quality, administers the DERA grant and rebate programs. The EPA awarded the first DERA grants in 2008, the American Recovery and Reinvestment Act (Recovery Act) grants in 2009, and grants from funds appropriated in Fiscal Years (FY) 2009 through 2018. This Fourth Report to Congress summarizes results from FY 2008-2013 and details a combination of final and estimated results from FY 2014-2016.

Since 2008, the DERA program has provided a range of benefits, summarized in Exhibit 1 below.

In the early years of DERA, many applicants requested funding for retrofits of on-highway vehicles, especially long-haul trucks and school buses. As the DERA program progressed and the EPA's on-highway 2007 standards were implemented, applicants sought to replace larger vehicles, vessels and equipment in ports and rail yards. Exhibit 2 shows the most frequently funded sectors for FY 2008-2016.

Exhibit 2: DERA Funded Sectors 2008-2016

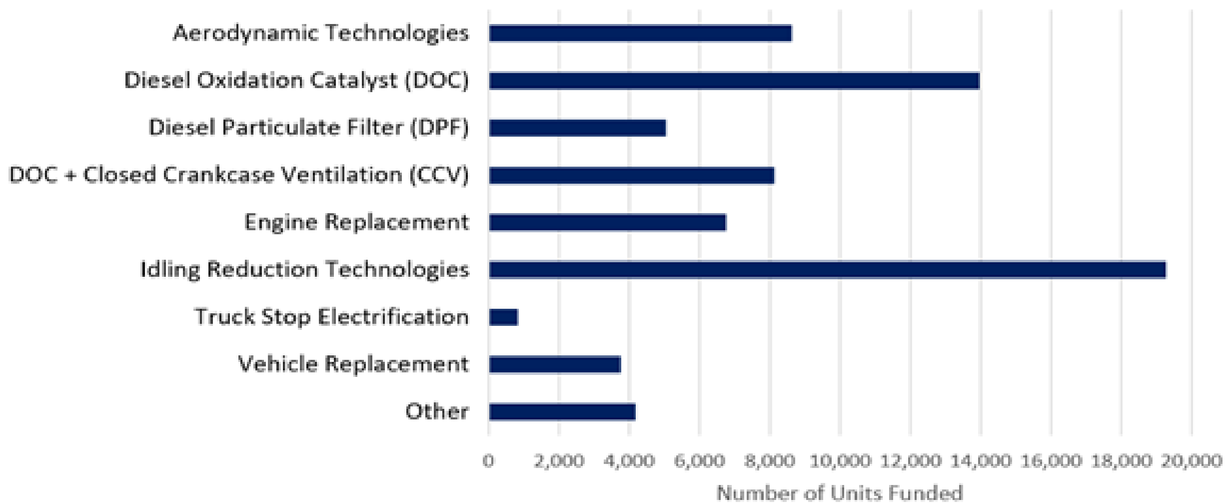



Exhibits 3 and 4 on page 13 show the technologies funded and the locations of the programs. Exhibit 4 is a map of DERA award recipients.

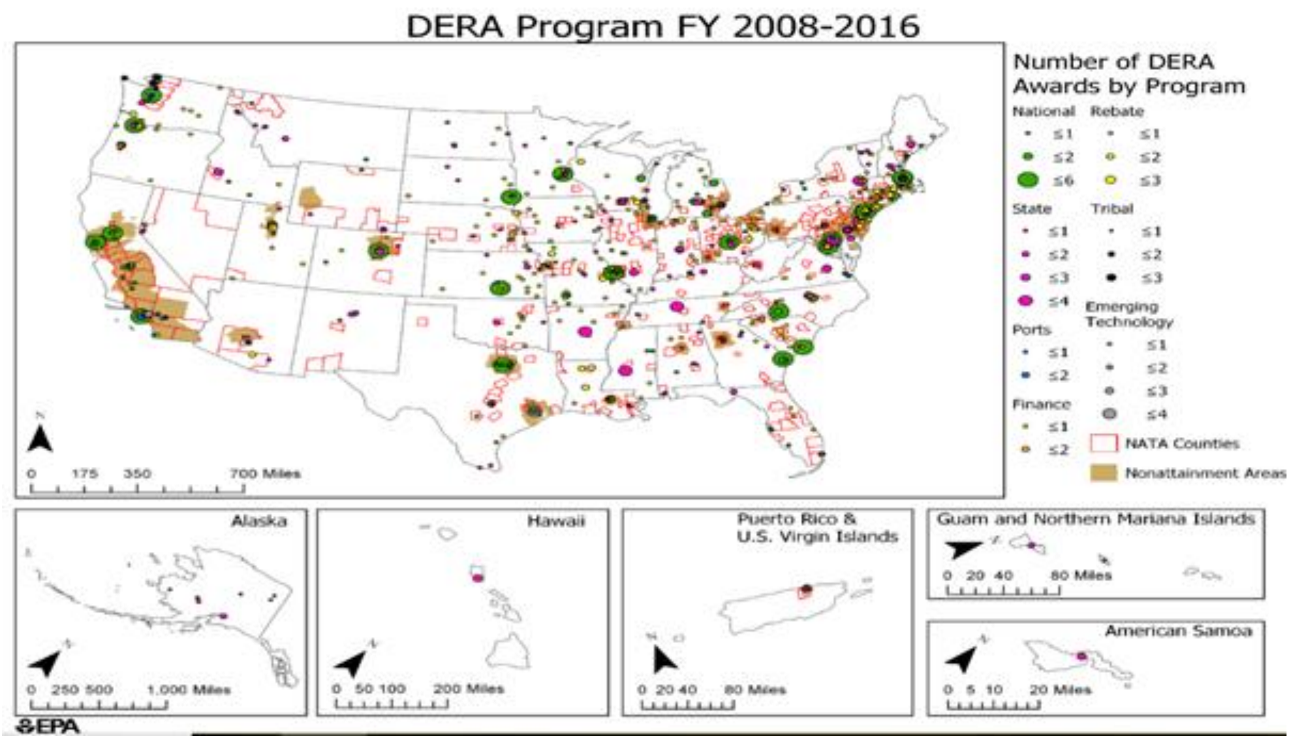
Exhibit 1: DERA Program Benefits and Accomplishments (FYs 2008-2016)

| Investment of DERA Program | Emission and Fuel Reductions |
|---|---|
| $629 million funds awarded | 472,700 tons of $NO_x$ |
| 67,300 engines retrofitted or replaced | 15,490 tons of PM |
| Up to $19 billion in monetized health benefits | 17,700 tons of hydrocarbon |
| Up to 2,300 fewer premature deaths | 61,550 tons of carbon monoxide |
| 64% of projects targeted to areas with air quality challenges | 5,089,170 tons of carbon dioxide |
| 3:1 leveraging of funds from non-federal sources | 454 million gallons of fuel saved |

## Exhibit 3: DERA Funding by Technology Type, 2008-2016




## Exhibit 4: DERA Program Map



**2017 AND BEYOND FUNDING**

The EPA has awarded DERA funding for FY 2017 and FY 2018 grants and rebates; these will be addressed in the next report to Congress, after the projects are finalized or close to completion. The EPA will continue to target its funding to areas that suffer from poor air quality, especially working with port communities. The national RFP prioritizes projects that reduce emissions from engines involved in goods movement and freight industries. The EPA prioritizes projects that engage local communities and provide lasting benefits, based on the size of the legacy fleet ("Legacy engines" are defined by the DERA program as the operating nonroad diesel and medium to heavy-duty highway diesel engines with engine model years 2006 and earlier.) and past demand for rebate funding exceeding availability, with $5 in requests for every $1 available. Subject to available appropriations, the EPA plans to continue to offer rebate funding to encourage fleet turnover for engines that pre-date the EPA's on-highway standards for PM (engine MY 2006 or older).

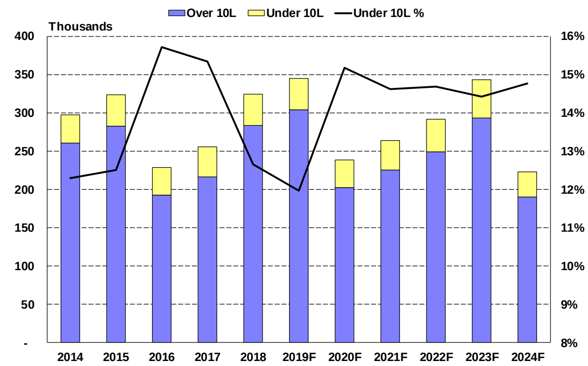
Direct emissions from diesel engines, especially particulate matter (PM), nitrogen oxides ($NO_X$), and sulfur oxides ($SO_X$), as well as other air toxins, contribute to health problems. Additionally, $NO_X$ contributes to the formation of ozone and PM through chemical reactions. PM has been associated with an increased risk of premature mortality, increased hospital admissions for heart and lung disease, and increased respiratory symptoms. Long-term exposure to components of diesel exhaust, including diesel PM and diesel exhaust organic gases, are likely to pose a lung cancer hazard. Exposure to ozone can aggravate asthma and other

respiratory symptoms, resulting in more asthma attacks, additional medication, lost school and workdays, increased emergency room visits and hospitalizations, and even premature mortality. Repeated exposure to ozone can increase susceptibility to respiratory infection and lung inflammation, and can aggravate preexisting asthma. At sufficient concentrations, ozone can even cause permanent damage to the lungs, resulting in the development of chronic respiratory illnesses. Children, outdoor workers, those who exercise outside, people with heart and lung disease, and the elderly are most at risk. The technologies used in DERA grants can reduce PM emissions by up to 95% and $NO_X$ by up to 90%. Each of these reductions makes an immediate and positive impact on public health. PM and $NO_X$ controls have been the primary focus for the time period of this report. For more information on health effects, see Health Assessment Document for Diesel Engine Exhaust, which examines information regarding the health hazards associated with exposure to diesel engine exhaust.
(https://www.epa.gov/sites/production/files/2019-07/documents/420r19005.pdf)

In this section, we will summarize the Classes 5-7 and Class 8 engine markets. This report is based on ACT's August N.A. *OUTLOOK* forecasts, with forecasts through 2024. Analysis of engine history and related forecasts highlight trends in engine type and displacement.

New engine introductions, as well as revisions to existing engines and emission impacts, will lead to changes in equipment that customers demand. The trend is generally toward smaller displacements; although in medium-duty applications, V8 and V10 gasoline engines continue to play a prominent and expanding role.

**N.A. Class 8 Production by Engine Displacement**




Source: RAI, ACT Research Co., LLC Copyright 2019

## HEAVY DUTY (CLASS 8) ENGINES

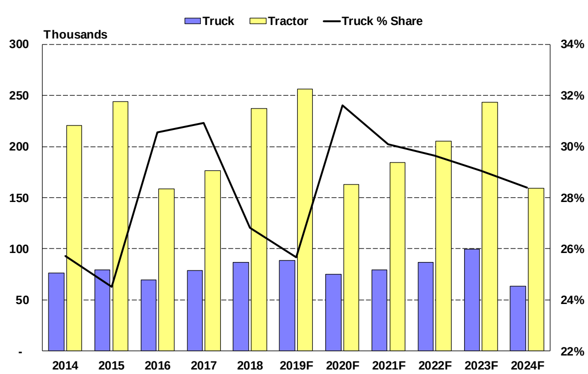
### 2019 & 2023 CLASS 8 PRODUCTION PEAKS

The forecast for Class 8 production of trucks and tractors is similar to the last quarterly engine report. Following the current cycle peak in 2019, at 345,000 units, NA Class 8 production is expected to fall substantially in 2020, with gains in subsequent years ahead of a new peak of almost 343,000 in 2023.

In 2024, a major reduction is projected as new, higher cost and more complex emission trucks are introduced in California and other CARB-compliant states. Production is forecast to drop below 223,000 units, the lowest total since 2010.

Truck demand tends to be less cyclical than that of tractors, so the truck proportion hits a low of 25.7% in this year's high production, rising in 2020 to 31.6%, before gradually dropping to 29% in 2024.

**N.A. Production Class 8 Truck vs. Tractor**




Source: RAI, ACT Research Co., LLC Copyright 2019

### ENGINES OVER 10L CONTINUE TO DOMINATE CLASS 8 PRODUCTION

Engines over 10L are projected to account for more than 85% of the Class 8 production between 2020 and 2024. Smaller displacement engines are used primarily in truck chassis, so the proportion of engines under 10L falls when tractor demand peaks. In 2019, only 12% of Class 8 production is forecast to use engines under 10L.

While the proportion increases to just below 15% through 2024, no dramatic increase in the use of engines under 10L is projected with new emission Class 8 trucks and tractors.

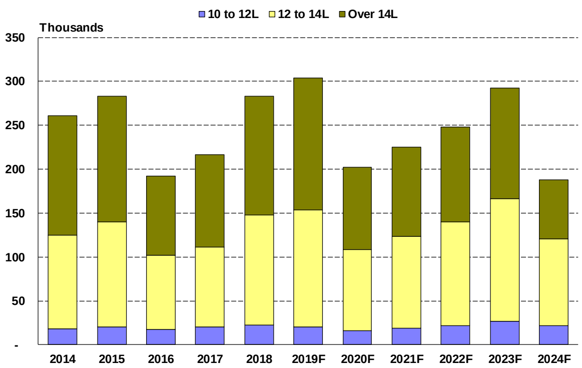
The forecast for premium over 10L engines is unchanged from the prior forecast, with an annual average of 243,000 for the five-year span of 2019 to 2024. This compares with 240,000 units for the previous five-year period of 2013 to 2018.

### TREND TO SMALLER DISPLACEMENTS OVER 10L CONTINUES

A trend to smaller displacement engines over 10L continues, although the over 14L category will remain the largest segment in 2019. This segment has strengthened this year, with forecast production at 150,000 units, thanks to strong demand for Cummins' X15 engine at Navistar and PACCAR.

Engines in the 12 to 14L categories continue to gain volume; this year's outlook is for 133,000 units. Next year's volume falls to 93,000, which is similar to the over 14L category volume. From 2021, the 12 to 14L segments are projected to grow faster than the over 14L segment, to become the largest category.

**N.A. Production Over 10L by Displacement**




Source: RAI, ACT Research Co., LLC Copyright 2019

The smallest displacement premium engines from 10 to 12L are forecast at 20,000 units in 2019, a slight reduction from 2018 that is due to very strong tractor demand. However, volume and share of Class 8 production is anticipated to increase through 2023, with 22,000 units forecast for 2024.

### TREND TO SMALLER DISPLACEMENTS TO ACCELERATE IN 2024

Both truck and tractor segments show a continuing movement to smaller displacements, with an acceleration prompted by new emission regulations expected in 2024.

By 2024, nearly 61% of tractors are forecast to have engines under 14L, compared with about 47% in 2018. Trucks use a higher proportion of smaller engines, with little over 78% under 14L in 2018, and growth expected to reach more than 80% in 2024.

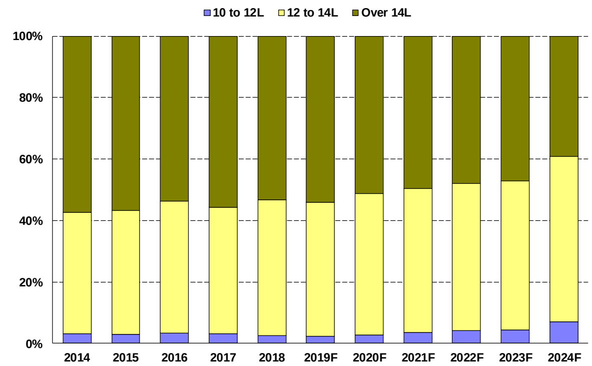
### UNDER 10L ENGINES IMPORTANT TO TRUCKS

The majority of engines (90%+) under 10L capacity are used in vocational trucks, where demand is more stable than for tractors.

In 2018, under 10L production in Class 8 trucks and tractors totaled just over 41,000 units, with 2019 forecast to be similar. Production is expected to drop in 2020, before recovering through 2023, when the total is forecast at 49,400 units. In 2024, in line with Class 8 overall, production is forecast to contract sharply, to 33,000 units.

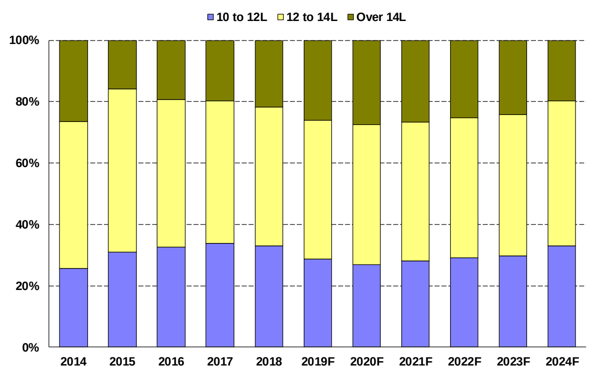
The 8-9L category is dominated by the Cummins L9, but recent OEM engine introductions from Daimler and Hino will gain share. The 7-8L category increase follows Detroit's DD8 engine introduction.

**N.A. Production Over 10L in Tractors**



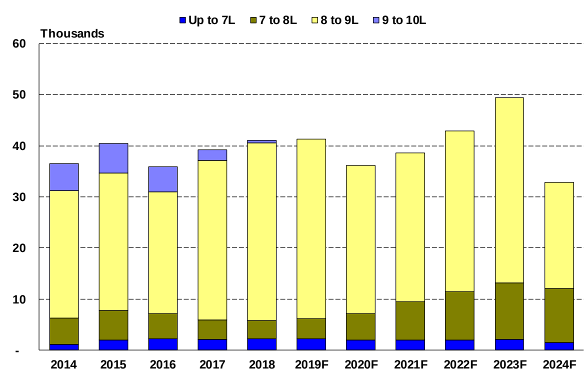

Source: RAI, ACT Research Co., LLC Copyright 2019

**N.A. Production Over 10L in Trucks**




Source: RAI, ACT Research Co., LLC Copyright 2019

**N.A. Production Class 8 Under 10L**




Source: RAI, ACT Research Co., LLC Copyright 2019

### OEM ENGINES GAIN SHARE

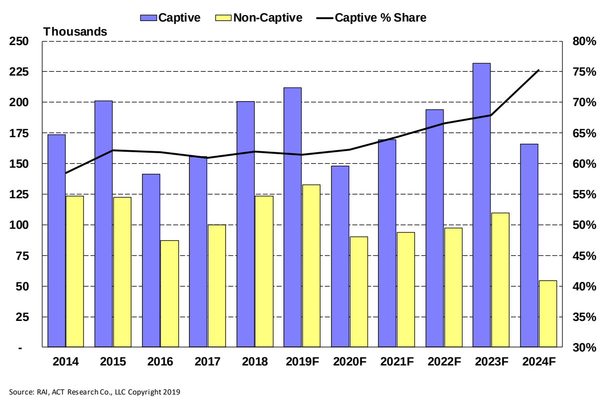
Captive engine penetration remained stable from 2016 through 2019, but it is forecast to increase beginning next year.

For 2019, the captive share of Class 8 production is forecast at just over 61%. OEM's share was restricted by limited availability of some OEM engines in the current high-demand market. As overall truck production falls, and new OEM engines are introduced, the captive share should increase through 2024. Our forecast of captive engine penetration is unchanged for 2024, at 74.5%.

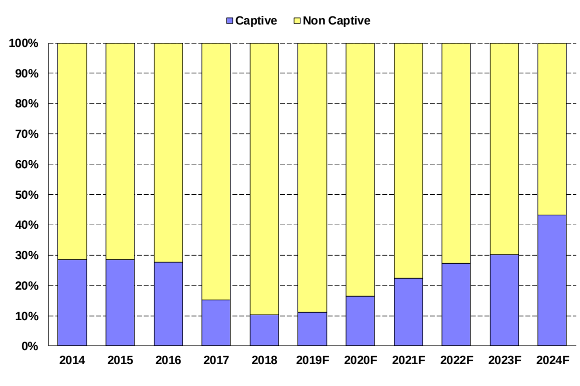
Captive engines dominate the over 10L market, but Cummins is forecast to maintain a strong position. Since 2016, Cummins has maintained its share, with strong demand for the X15 engine, but the forecast shows movement to captive engines, especially by the end of the forecast horizon.

In the under 10L segment, Cummins currently has almost 90% of the market in Class 8 trucks and tractors, but new OEM engine entries will begin to reduce Cummins' dominance. By 2024, 40% of volume is projected to be with OEM engines.

**N.A. Production Class 8 Captive vs. Non-Captive Engines**




**N.A. Production Class 8 Under 10L Source**




### CUMMINS RETAINS POSITION AT MAJOR OEMs

The listing of available Class 8 engines on the following page is unchanged. Cummins supplies its X15 engine to all OEMs, with most volume at Navistar and PACCAR. The X12 engine has limited presence, with only Freightliner, Western Star and specialty OEMs listing it as available. The prior ISX12 engine had strong demand in Kenworth and Peterbilt trucks, but the two PACCAR companies prefer to promote the in-house PACCAR MX11 and MX13 engines.

All OEMs offer the Cummins-Westport ISX12N natural gas engine, and it remains the only large displacement NG engine available in North America.

### INTEGRATED COMPONENTS BEYOND ENGINES GAIN GROUND

As well as engines, Class 8 OEMs are vertically integrating other components into their trucks and tractors. (See supplier/OEM table on the following page for more details.) Daimler and Volvo engines are coupled with in-house AMT designs, with penetration rates in tractors around 90%. Both companies also offer in-house axle and suspension systems that further differentiate brands and capture lucrative after-sales revenues.

PACCAR's trucks are also integrated, although the company uses agreements with suppliers to add the PACCAR brand to Cummins engines below 10L, Eaton AMT transmissions, and Meritor axles.

Navistar currently has only one engine, the 12.4L A26, that is in-house and uses suppliers for other major components. However, as the company integrates its future products with Traton Group, we expect an increase in the number of in-house components.

### CUMMINS' L9 RETAINS DOMINANT POSITION IN THE UNDER 10L SEGMENT

Cummins L9 is the engine of choice for most Class 8 trucks and tractors under 10L. New competition from Daimler, Hino and potentially Navistar, through its Traton affiliation, will begin to impact Cummins' volume.

Cummins' B6.7 has a limited role in Class 8 trucks, primarily in municipal applications, and Ford offers its PowerStroke 6.7L V8 in Ford F750 models over 33,000 lbs., in limited volume.

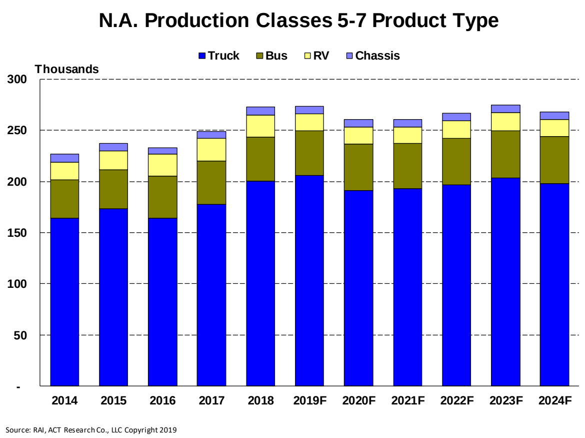
**Heavy Duty Class 8 Over 10L Diesel Engine HP and Torque Ranges**

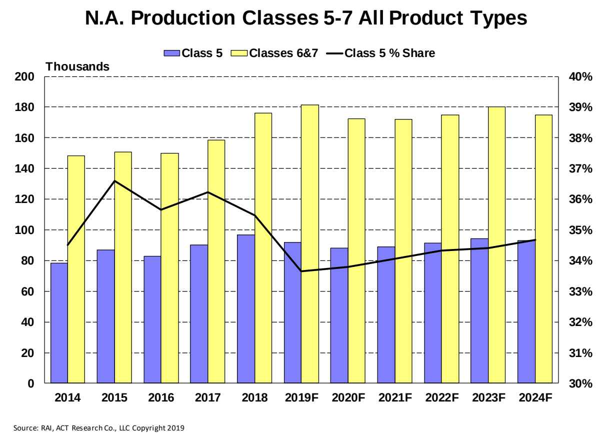
| Engine | Type | Displ (L) | Future | Emission | HP | | Torque lb-ft | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Low | High | Low | High |
| Cummins X12 | L6 | 11.8 | | 17 | 350 | 500 | 1250 | 1700 |
| Cummins X15 Performance | L6 | 14.8 | | 17 | 485 | 605 | 1650 | 2050 |
| Cummins X15 Economy | L6 | 14.8 | | 17 | 400 | 500 | 1450 | 1850 |
| Cummins ISX15 Smart Advantage | L6 | 14.8 | | 17 | 400 | 500 | 1450 | 1850 |
| Cummins ISX15 | L6 | 14.8 | | 13 | 400 | 605 | 1650 | 2050 |
| Detroit DD11 | L6 | 10.7 | ✓ | EU VI | 326 | 428 | 1254 | 1549 |
| Detroit DD13 | L6 | 12.8 | | 17 | 350 | 505 | 1250 | 1850 |
| Detroit DD15 | L6 | 14.8 | | 17 | 400 | 505 | 1550 | 1750 |
| Detroit DD16 | L6 | 15.6 | | 17 | 500 | 600 | 1850 | 2050 |
| Navistar A26 | L6 | 12.4 | | 17 | 370 | 475 | 1350 | 1750 |
| *Navistar (VW Group) New* | *L6* | *13.0* | ✓ | *21* | *400* | *500+* | *1450* | *1850+* |
| Paccar MX-11 | L6 | 10.8 | | 17 | 335 | 430 | 1150 | 1650 |
| Paccar MX-13 | L6 | 12.9 | | 17 | 405 | 510 | 1450 | 1850 |
| Volvo D11 (Mack MP7) | L6 | 10.8 | | 17 | 325 | 425 | 1250 | 1560 |
| Volvo D13 (Mack MP8) | L6 | 12.8 | | 17 | 415 | 505 | 1450 | 1860 |

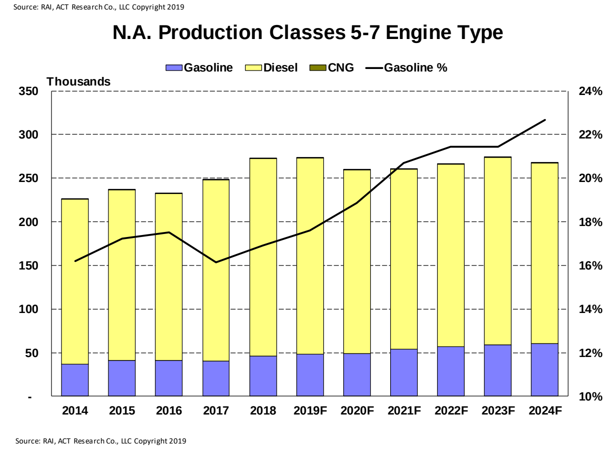
| | Daimler | | Paccar | | Volvo-Mack | | Navistar | |
|---|---|---|---|---|---|---|---|---|
| | OEM | Supplier | OEM | Supplier | OEM | Supplier | OEM | Supplier |
| **Engine over 10L** | Detroit | Cummins | Paccar | Cummins | Volvo | Cummins | Navistar | Cummins |
| **Engine under 10L** | Detroit | Cummins | Paccar branded supplied by Cummins | | - | Cummins | - | Cummins |
| **Engine Natural Gas** | - | Cummins | - | Cummins | - | Cummins | - | Cummins |
| **Transmission AMT** | Detroit | Eaton | Paccar branded supplied by Eaton | Eaton | Volvo | Eaton | - | Eaton |
| **Transmission Automatic** | - | Allison | - | Allison | - | Allison | - | Allison |
| **Axle** | Detroit | Various | Paccar branded supplied by Meritor | Various | Volvo | Various | - | Various |
| **Suspensions** | Detroit | Various | Paccar | Various | Volvo | Various | Navistar | Various |

**Class 8 Under 10L Diesel Engine HP and Torque Ranges 2018+**

| Engine | Type | Displ (L) | Future | HP | | Torque lb-ft | |
|---|---|---|---|---|---|---|---|
| | | | | Low | High | Low | High |
| Cummins ISB7 Performance | L6 | 6.7 | | 280 | 325 | 660 | 750 |
| Cummins ISB7 Productivity | L6 | 6.7 | | 200 | 260 | 520 | 660 |
| Cummins L9 Performance | L6 | 8.9 | | 370 | 380 | 1250 | 1250 |
| Cummins L9 Productivity | L6 | 8.9 | | 260 | 350 | 720 | 1150 |
| Cummins L9N | L6 | 8.9 | | 250 | 320 | 660 | 1000 |
| Detroit DD8 | L6 | 7.7 | | 230 | 350 | 660 | 1050 |
| Ford PowerStroke ` | V8 | 6.7 | | 275 | 330 | 675 | 725 |
| Hino A09 | L6 | 8.9 | | 300 | 360 | 900 | 1150 |
| New Navistar (Traton Group) | L6 | 9.0 | ✓ | 330 | 400 | 1100 | 1330 |




## MEDIUM-DUTY (CLASSES 5-7) ENGINES

### MEDIUM DUTY PRODUCTION STABLE

A rear-view mirror look to 2010 highlights the medium duty segment's recovery from the recession, and its relative stability anticipated through 2024 for Classes 5-7 production.

2018 North American medium duty Classes 5-7 production totaled 272,700 units, while the 2019 through 2024 average annual volume is forecast at 267,200 units. In contrast to Class 8, the reduction in 2024 for emission changes, at less than 3%, is modest.

Trucks represent around 74% of medium duty production. RV production has declined in 2019 and is anticipated to continue at a lower level through 2024. Other segments show stability.

### CLASSES 6-7 GAIN RELATIVE TO CLASS 5

Classes 6-7 production grew quicker than Class 5 from 2016 to 2019, as the Class 5 market matured. As well, the age of Classes 6-7 vehicles is older than Class 5, and the recent higher level of production refelects replacement of older vehicles. However, Class 5 is expected to retain a consistent 35% share of medium duty production through 2024.

Revised Ford and Ram Class 5 truck products will be available for 2020 MY. GM and Navistar have launched an all-new Classes 4-6 conventional truck, with GVWR to 23,500 lbs. And, Ford will add a Class 6 F600 model in mid-2020 CY, with a GVWR upgrade at 22,000 lbs. from its Class 5 F550. These new Class 6 products likely will encourage some users to upgrade from Class 5.

### GASOLINE ENGINE PENETRATION TO INCREASE

In 2017, medium duty gasoline penetration was 16.1% and it increased to 16.9% in 2018, Ford's gasoline engines accounting for most of the volume. Ford's new F600 model will be available with a gasoline option, supplementing the manufacturer's existing F650 and F750 entries.

Ford's new purpose-designed 7.3L V8 gasoline engine for 2020 MY will replace the 6.8L V10 in all commercial products. Blue Bird uses Ford's gasoline engines in its school bus chassis either in gasoline, propane or natural gas, and will also move to use the new 7.3L engine.

GM and Navistar are expected to add GM's 6.6L V8 gasoline engine to their new Classes 4 through 6 conventional chassis cabs for 2021 MY. Fuso and Isuzu will expand their gasoline models into Class 5 LCF trucks, which are currently restricted to Classes 3-4. GM-based gasoline engine designs are also used by Freightliner and International.

### FORD's 2020 7.3L GASOLINE ENGINE DESIGNED FOR COMMERCIAL TRUCKS

Ford's new 7.3L gasoline engine for 2020 MY is designed specifically for commercial truck applications. It's a conservative design that will replace Ford's 6.8L V10 engine in all heavier commercial truck uses: F450/F550/F600 chassis cabs, E450 cutaways, motorhome and F650/F750 medium duty.

The 7.3L has increased displacement, but reverts to an overhead valve design rather than the overhead cam valvetrain of the 6.8L. The OHV format is inherently simpler and lower cost, but importantly supplies low-end torque required in commercial and towing applications.

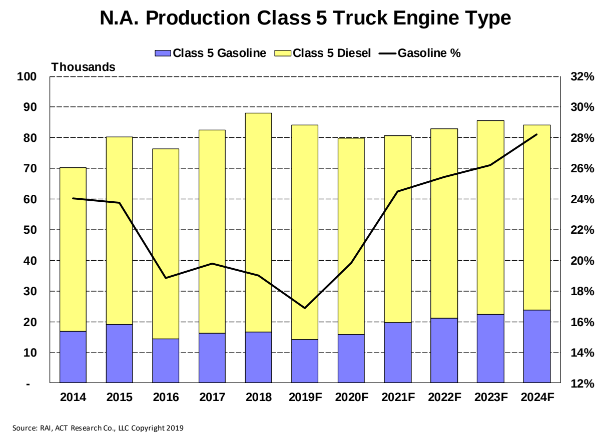
The naturally aspirated, conventional port fuel injected 7.3L is designed for 87 octane and use with propane and natural gas fuels. Components are designed for durability and reliability. Valve seats and piston rings use materials from the PowerStroke 6.7L diesel engine and roller tappets used in carbon-nitride bearings.

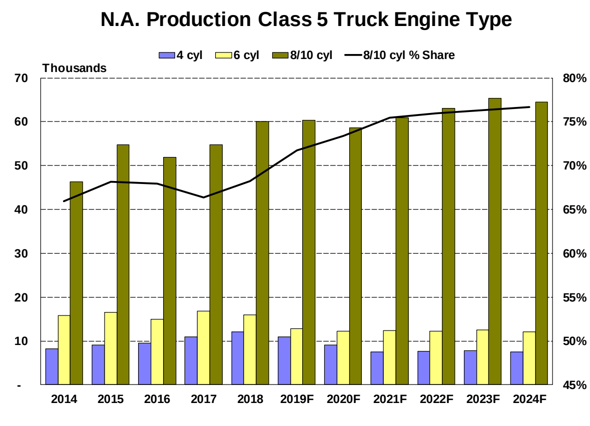
In heavier commercial applications, it is rated at 350 HP, with 468 lb-ft and 3,900 rpm. In lighter pickup applications through Class 3, the engine makes 430 HP and 475 lb-ft. torque. The 7.3L, as well as the revised PowerStroke diesel engine for 2020 MY, will utilize a new 10-speed transmission; although, medium duty F650/F750 models will continue to have the current 6-speed transmission.

### GASOLINE ENGINES GAIN IN CLASS 5 USE

Gasoline engines had a 25% penetration in 2018 and although a reduction is forecast for 2019, gasoline penetration is expected to increase with Ford's new 7.3L engine, plus GM, Isuzu and Fuso Class 5 gasoline entries.

Gasoline engines have proved durable for many Class 5 applications, and lower mileage users appreciate the low initial price, lower priced gasoline and reduced complexity versus diesel engines. Gasoline engines offer low cost alternative fuel conversions, with propane being the most popular, especially in stripped chassis.




The penetration of gasoline engines in Class 5 is forecast to rise almost 33%, a slight increase over our prior forecast.

### V-CONFIGURATION ENGINES DOMINATE THE CLASS 5 SEGMENT

V-configuration engines from Ford, GM and Ram dominate in Class 5, further increasing penetration through 2024.

4-cylinder engines are used almost exclusively in low cab forward trucks, and the major 6-cylinder volume in the Cummins B-Series in Ram chassis cabs.

### CLASSES 6-7 PRODUCTION REMAINS STABLE

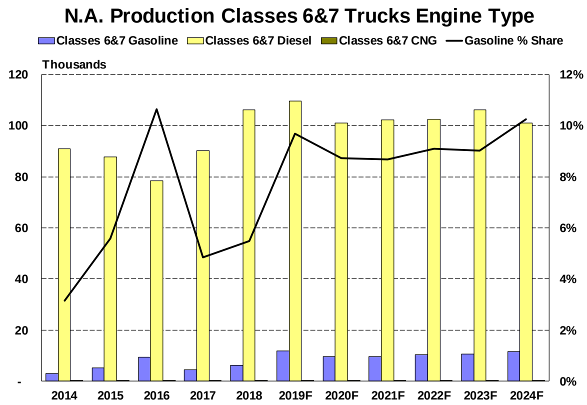
Classes 6-7 production was 176,000 in 2018, with stability expected through 2024. The forecast for annual average Classes 6-7 production from 2019 to 2024 is also 176,000 units.

Trucks dominate this market, followed by school bus chassis. The RV segment is moderating, after some strong recent years.

### GASOLINE PENETRATION EXPECTED TO INCREASE TO 10% FOR CLASSES 6-7 TRUCKS

Gasoline penetration slowed in 2017 and 2018, but has recovered in 2019. The forecast holds penetration close to 10% through 2024.

Ford's new 7.3L gasoline engine and the new GM and Navistar Class 6 conventional gasoline entry into Class 6 help maintain the improved gasoline penetration.




Source: RAI, ACT Research Co., LLC Copyright 2019

### DEMAND FOR GASOLINE-BASED ENGINES INCREASES IN BUS CHASSIS MARKETS

All three school bus manufacturers offer gasoline engines that can run on gasoline, propane, or natural gas. Propane has had significant acceptance in school buses, offering a low-cost method to a more environmentally-friendly fuel to use around school children than diesel. Blue Bird has been the leader, using Ford's 6.8L gasoline engine, with conversions engineered by Rousch Clean Tech. Thomas Bus and Navistar's IC Bus utilize GM-derived engines, engineered by Power Solutions International (PSI).

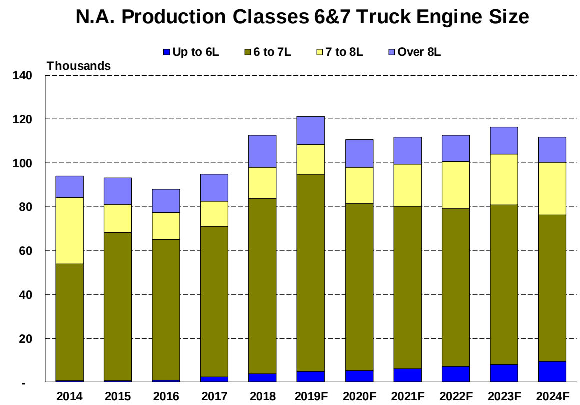
The forecast assumes additional school bus users will adopt gasoline-based engines. Natural gas is available from Cummins-Westport, but the high cost compared with propane conversions restricts acceptance.

All three school bus manufacturers, plus Lion Bus, are developing electric buses, with units already in operation. Longer term, school buses will be an opportunity for electric vehicles.

### MINOR CHANGES ANTICIPATED TO ENGINE DISPLACEMENT IN CLASSES 6-7 TRUCKS

Classes 6-7 trucks are forecast to have some reduction in engine size through 2024, principally with increased use of engines below 6L, which are all 4-cylinder type.

Cummins B-Series accounts for the majority of 6-7L volume, although Ford and Hino also have models available for use in the segment. The 7-8L category is expected to increase as Detroit's DD8 engine gains share and the over 8L segment remains stable with Cummins L9 and some Hino volume added.




Source: RAI, ACT Research Co., LLC Copyright 2019

### COMMERCIAL CHASSIS SEGMENT PROVIDES OPPORTUNITY FOR EV ADOPTION

The commercial chassis, or stripped chassis, segment in Classes 5-7 is relatively stable, at around 7,500 units annually. Gasoline-based engines dominate the segment, although many are converted to alternative fuels, primarily propane.

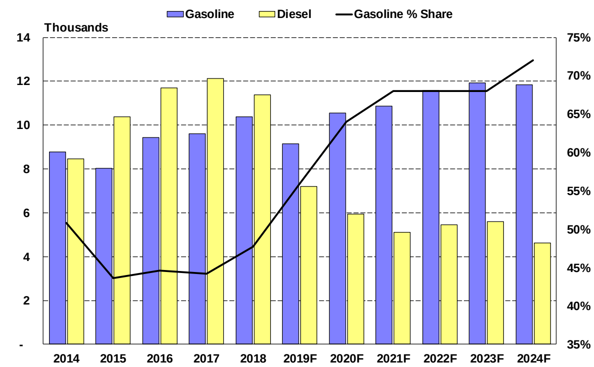
The limited daily mileage in urban areas, with daily return-to-base operation, makes for an easier adoption of electric power than most other segments, especially as many of the users pursue green technologies to enhance their corporate images.

## GASOLINE GAINS IN THE RV CHASSIS MARKET

The RV chassis segment in Classes 5-7 volume in 2019 is expected to decline, after strong production in recent years. This is the beginning of a downward trend forecast through our 2024 outlook horizon.

Ford is the leading RV supplier, exclusively with gasoline engines, and its new 7.3L will improve its competitiveness against higher-priced diesel chassis. The forecast shows gasoline penetration increasing to 70% by 2024, from around 55% in 2019.

**N.A. Production Classes 5-7 RV by Engine Type**




Source: RAI, ACT Research Co., LLC Copyright 2019

**MD DIESEL ENGINES IN CLASSES 4-7:**

Cummins announced that its V5.0L engine will be discontinued by the end of 2019. Nissan was the primary volume user in its Class 2 Titan XD, but medium duty applications never gained acceptance, outside of a few school buses. The listing of other available diesel engines is unchanged.

Daimler, Hino and Isuzu offer 4-cylinder engines in Class 5; Daimler extends its DD5 into Class 7 and Isuzu currently offers its 4H engine into Class, 6 at 25,950 lbs. GVWR.

Ford's 6.7L V8 diesel is available in GVWRs through Class 7, with a few produced for use in Class 8. GM's Duramax 6.6L engine has returned to Classes 4-6 in the new GM-Navistar conventional truck.

All other diesel engines in Classes 5-7 are L6 configurations.

| Medium Duty Class 4-7 Diesel Engine HP and Torque Ranges | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Engine | Type | Displ (L) | HP | | Torque lb-ft | | LD | Class 4-7 Application | | | |
| | | | Low | High | Low | High | <14K | Truck | Bus | Chassis | M-Home |
| ~~Cummins V5.0 (Pickup)~~ | ~~V8~~ | ~~5.0~~ | | ~~310~~ | | ~~555~~ | ~~✓~~ | | | | |
| ~~Cummins V5.0~~ | ~~V8~~ | ~~5.0~~ | ~~200~~ | ~~275~~ | ~~500~~ | ~~560~~ | | ~~✓~~ | ~~✓~~ | ~~✓~~ | ~~✓~~ |
| Cummins ISB (2&3) | L6 | 6.7 | 370 | 400 | 860 | 1000 | ✓ | | | | |
| Cummins ISB (4&5) | L6 | 6.7 | 325 | 360 | 750 | 800 | | ✓ | | | |
| Cummins B6.7 Performance | L6 | 6.7 | 280 | 325 | 660 | 750 | | ✓ | ✓ | ✓ | ✓ |
| Cummins B6.7 Efficiency | L6 | 6.7 | 200 | 260 | 520 | 660 | | ✓ | ✓ | ✓ | ✓ |
| Cummins L9 Performance | L6 | 8.9 | 370 | 380 | 1250 | 1250 | | ✓ | ✓ | | ✓ |
| Cummins L9 Productivity | L6 | 8.9 | 260 | 350 | 720 | 1150 | | ✓ | ✓ | | ✓ |
| Detroit DD5 | L4 | 5.2 | 210 | 230 | 520 | 660 | | ✓ | ✓ | ✓ | |
| Detroit DD8 | L6 | 7.7 | 230 | 350 | 660 | 1050 | | ✓ | ✓ | | ✓ |
| Ford PowerStroke (2&3) | V8 | 6.7 | | 450* | | 935* | ✓ | | | | |
| Ford PowerStroke (4&5) | V8 | 6.7 | 330 | 330* | 750 | 750* | | ✓ | ✓ | | |
| Ford PowerStroke (6&7) | V8 | 6.7 | 275 | 330 | 675 | 725 | | ✓ | | | |
| Fuso FPT 3.0 (3&4) | L4 | 3.0 | 161 | 161 | 295 | 295 | | ✓ | | | |
| GM Duramax 2019 MY (2&3) | V8 | 6.6 | | 445 | | 910 | ✓ | | | | |
| GM Duramax 2019 MY (4-6) | V8 | 6.6 | | 350 | | 700 | | ✓ | | | |
| Hino J05 | L4 | 5.2 | 210 | 210 | 440 | 440 | | ✓ | | | |
| Hino J08 | L6 | 7.8 | 230 | 260 | 520 | 660 | | ✓ | | | |
| Hino A09 (2020 MY) | L6 | 8.9 | 300 | 360 | 900 | 1150 | | ✓ | | | |
| Isuzu 4H | I4 | 5.2 | 215 | 240 | 452 | 520 | | ✓ | | | |
| * 2019 Ratings. Increase expected for 2020 MY | | | | | | | | | | | |

**MD GASOLINE ENGINES IN CLASSES 4-7:**

Both Ford and GM announced new gasoline engines in February 2019, with Ford recently providing the HP and torque data for its new 7.3L engine. GM's data covers light duty performance, and an anticipated medium duty application will offer lower HP and torque.

Ford's new 7.3L is designed as a simple, low-cost, more durable and reliable gasoline engine than its V10 6.8L predecessor. It should also be more fuel efficient. It will be the standard engine in Ford commercial products for 2020 MY.

GM's new gasoline V8 has an increased displacement of 6.6L for the 2020 MY 2500HD and 3500HD Series. Unlike Ford's new 7.3L, it uses direct fuel injection not immediately adaptable to alternative fuels.

| Medium Duty Class 4-7 Gasoline Engine HP and Torque Ranges | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Engine | Type | Displ | HP | Torque | LD | MD Application | | | | MD Class | | | | MD Fuel | | |
| | | (L) | | lb-ft | <14K | Truck | Bus | RV | Chassis | 4 | 5 | 6 | 7 | Gasoline | Propane | CNG |
| Ford Triton MD | V10 | 6.8 | 320 | 460 | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Ford Triton F450/550 | V10 | 6.8 | 288 | 424 | | ✓ | | | | ✓ | ✓ | | | ✓ | ✓ | ✓ |
| Ford 7.3L F250/350 pickup | V8 | 7.3 | 430* | 475* | ✓ | | | | | | | | | | | |
| Ford 7.3L | V8 | 7.3 | 350 | 468 | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Ram 6.4L LD | V8 | 6.4 | 410 | 429 | ✓ | | | | | | | | | | | |
| Ram 6.4L | V8 | 6.4 | 370 | 429 | ✓ | ✓ | | | | ✓ | ✓ | | | ✓ | | |
| GM 6.0L (Cutaway) | V8 | 6.0 | 341 | 373 | | ✓ | ✓ | ✓ | | ✓ | | | | ✓ | | |
| GM 6.0L Gasoline | V8 | 6.0 | 297 | 372 | | ✓ | | | | ✓ | | | | ✓ | ✓ | ✓ |
| GM 6.6L Gasoline MD | V8 | 6.6 | 350 | 400 | | ✓ | | | | ✓ | ✓ | ✓ | | ✓ | | |
| PI PIthon (GM based) | V8 | 8.0 | 339 | 495 | | ✓ | ✓ | | | | | | ✓ | | ✓ | |
| PI (GM L96) Gasoline | V8 | 6.0 | 322 | 380 | | ✓ | | | ✓ | ✓ | ✓ | ✓ | | ✓ | | |
| PI (GM LC8) Propane | V8 | 6.0 | 308 | 367 | | ✓ | | | ✓ | ✓ | ✓ | ✓ | | | ✓ | |
| PI (GM LC8) CNG | V8 | 6.0 | 282 | 320 | | ✓ | | | ✓ | ✓ | ✓ | ✓ | | | | ✓ |
| GM 6.6L Gasoline LD | V8 | 6.6 | 401* | 464* | ✓ | | | | | | | | | | | |
| PSI (GM based) | V8 | 6.0 | 297 | 373 | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | | |
| PSI (GM based) | V8 | 8.8 | 270 | 565 | | ✓ | ✓ | | | | | ✓ | ✓ | | ✓ | |
| * Under 14K GVWR ratings; future applications (estimate) | | | | | | | | | | | | | | | | |

## ALTERNATIVE POWER

### NG TRUCK PRODUCTION FAILS TO RETURN TO 2014 PEAK

Production of natural gas-powered trucks peaked in 2014, in response to high diesel fuel pricing, but declined in line with diesel prices. Committed users, particularly in refuse (and bus not counted here) are continuing to buy, but many trucking companies who tried natural gas have returned to diesel to power their fleets. Tractor volumes have fallen, whereas straight truck volumes are more stable.

Natural gas' advantage to dramatically reduce emissions compared with diesel trucks is important in markets like California. The increasing availability of renewable natural gas is another asset.

### CWI OFFERS 3 NEAR-ZERO VARIANTS

Cummins-Westport offers the only three diesel engine-derived natural gas engines in North America, and all are standardized on the near-zero derivatives.

The B6.7N is available for medium duty customers, but the high price, compared with lower-cost gasoline-derived engines that run primarily on propane, limits volume. The L9N and ISX12N are targeted at the heavy duty applications.

### SLOWER GROWTH FORECAST FOR NG

The outlook for natural gas is for limited growth in volume, although penetration remains below 2% of Class 8. Also, there is an increasing threat from EVs as an option for users looking to reduce emissions, towards the end of the forecast period.

In medium duty, Classes 5-7 natural gas-powered trucks using Cummins-Westport engines have been slow to gain acceptance; the school bus market offers the greatest opportunity for growth, although volumes will remain low.

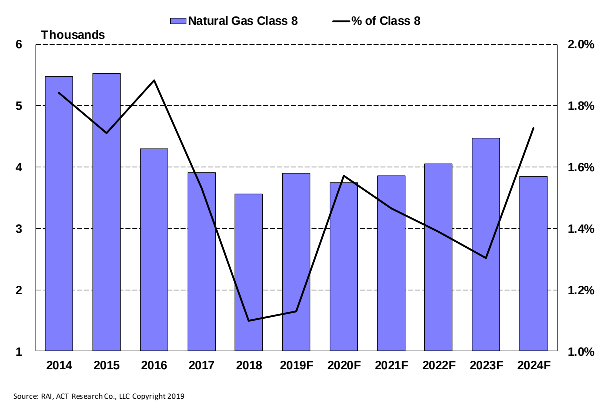
### ELECTRIC CVs TO GAIN MOMENTEM BY 2024

The forecast for electric-powered commercial vehicles is unchanged. Major OEMs and suppliers are actively involved in development and testing, with firm plans to enter production over the next couple of years, following extensive trial applications.

Start-up companies are more aggressive with their entry plans, but most vehicles are in the concept stage, with almost no real-world testing; infrastructure and production plans are also in preparatory stages.

Consistent but slow growth is projected for electric vehicle for the next 2-3 years, but 2024 emissions could drive more customers to investigate how electrification can fit into their trucking needs. The forecasts for medium and heavy duty do not include transit buses, currently the lead application for medium/heavy electric vehicles.

**N.A. Production Class 8 Natural Gas**




| Natural Gas HP and Torque Ranges and Applications 2018+ | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Truck | | | | Bus | |
| Engine | Type | Displ (L) | HP | | Torque lb-ft | | Up to 33K GVWR | Up to 66K GCWR | Up to 80K GCWR | Refuse | School/ Shuttle | Transit Coach |
| | | | Low | High | Low | High | | | | | | |
| Cummins B6.7N | L6 | 6.7 | 200 | 240 | 520 | 560 | ✓ | | | | ✓ | |
| Cummins L9N | L6 | 8.9 | 250 | 320 | 660 | 1000 | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Cummins ISX12N | L6 | 11.9 | 320 | 400 | 1150 | 1400 | | ✓ | ✓ | ✓ | | ✓ |

## ENGINE DEFINITIONS

North America is defined as the United States, Canada and Mexico.

The North American truck and bus market uses a variety of engine types including diesel, gasoline, alternative fuel, hybrid and electric.

- The diesel engine (also known as a compression-ignition or CI engine) is an internal combustion engine in which the fuel is ignited by the high temperature achieved when greatly compressed (adiabatic compression).
- The gasoline (petrol) engine is an internal-combustion engine with pistons driven by explosions of a mixture of air and vapor of gasoline or other volatile fuel ignited by an electric spark.
- An alternative fuel engine is an internal combustion engine that uses a fuel other than traditional petroleum fuels (gasoline or diesel). For this report, alternative fuels include compressed natural gas (CNG), liquid natural gas (LNG), propane (LPG) and bio-fuels.
- Hybrid power utilizes more than one form of onboard energy to achieve propulsion. In practice, that means a hybrid will have a traditional internal-combustion engine and one or more electric motors with battery pack.
- Electric power uses one or more electric motors or traction motors for propulsion. An electric vehicle may be powered through a collector system by electricity from off-vehicle sources, or may be self-contained with a battery.

There is a difference between what is considered heavy (Class 8) and medium (Classes 5-7) duty trucks and heavy, medium and light duty engines.

- Heavy-duty diesels (premium) are considered 10L displacement and above that are used in Group 2 Class 8 trucks/tractors and large buses and motor homes.
- Medium-duty diesels (non-premium) have displacements from 7L to 9.9L and are used predominantly in Group 1 Class 8 and Class 7 trucks.
- Light-duty diesels have displacements below 7L and are to be used in Classes 2 through 7 trucks (a few have even been used in Group 1 Class 8 trucks).

For this report, we will use the ACT heavy and medium-duty vehicle definitions and the engines used in those trucks regardless of displacement.

## FEDERAL REGULATIONS

Federal engine regulations have been the driving force in the vehicle market since the Clean Air Act of 1990. The actual regulations began in 1998.

### MD/HD EMISSION/FUEL ECONOMY REGULATIONS TIMING

| | | |
|---|---|---|
| Level 1 | 1998 | EPA ‘98 |
| Level 2 | 2002/2004 | EPA ‘04 |
| Level 3 | 2007 | EPA ‘07 |
| Level 4 | 2010 | EPA ‘10 |
| Level 5 | 2014-2017 | GHG-1 |
| Level 6 | 2021/2024/2027 | GHG-2 |

Over the past 17 years, most engines have added or required most of the following:

- Electronic controls
- DPF (Diesel Particulate Filter)
- NOx Catalyst
- Cooled EGR (Exhaust Gas Recycling)
- SCR (Selective Catalyst Regeneration) or urea dosing
- Additional powertrain cooling
- On-board diagnostics

Current truck diesel engine NOx and PM emissions regulations are the same as 2010 with no changes expected through 2027:

- PM - 0.01 g/bhp-hr
- NOx - 0.20 g/bhp-hr
- NMHC - 0.14 g/bhp-hr

## GHG & FUEL EFFICIENCY

US GHG emissions and fuel efficiency standards for heavy and medium-duty vehicles have been jointly developed by the EPA and NHTSA. NHTSA developed fuel consumption standards under the authority of the 2007 Energy Independence and Security Act (EISA), while the EPA developed a GHG emissions program under the Clean Air Act. The standards are applicable to all on-road vehicles rated at a GVW≥8,500 lbs, and the engines that power them. The website www.dieselnet.com is an excellent source for all engine and vehicle regulations.

The GHG/FE (fuel efficiency) standards were adopted in two phases:

- Phase 1 regulation, adopted on August 9, 2011, [EPA 2011], covers model years (MY) 2014-2018, with NHTSA fuel economy standards voluntary in MY 2014-2015.
- Phase 2 regulation, published on August 16, 2016, [EPA 2016], applies to MY 2021-2027 vehicles. The Phase 2 rule also introduces new standards for trailers, a category not previously regulated. The EPA trailer standards began in MY 2018 (for certain trailers), while NHTSA's standards take effect in MY 2021, with credits available for voluntary participation before then.
- Phases 1 and 2 standards are applicable nationwide. However, the California Air Resources Board (CARB) deemed the federal Phase 2 program not sufficiently strong to meet California GHG emission reduction goals. CARB started the development of *California Phase 2 GHG* emission standards for heavy-duty vehicles that would provide GHG emission reductions beyond those of the federal Phase 2 program. The CARB staff worked jointly with the US EPA and the NHTSA on GHG-2 for medium and heavy-duty vehicles. California is aligning with the federal Phase 2 standards in structure, timing, and stringency.

Under each phase, different $CO_2$ and fuel consumption standards are applicable to different categories of vehicles:

- Combination tractors (the semi-trucks that typically pull trailers): Phase 1 engine and vehicle standards began in MY 2014 and achieved 7-20% reduction in $CO_2$ emissions and fuel consumption by MY 2017 over the 2010 baselines. Phase 2 standards begin in MY 2021 and achieve 15-27% reduction in $CO_2$ emissions by MY 2027 over the 2017 baselines.
- Trailers: The standards started in MY 2018 and achieve 6-10% reduction in fuel consumption and $CO_2$ emissions by MY 2027 over the 2017 baselines.
- Vocational vehicles: Phase 1 engine and vehicle standards started in MY 2014 and achieved up to a 10% reduction in fuel consumption and $CO_2$ emissions by MY 2017 over the 2010 baselines. Phase 2 standards start in MY 2021 and require a 10-18% reduction in $CO_2$ emissions from gasoline vehicles and a 12-24% $CO_2$ emission reduction from diesel vehicles by MY 2027 over the 2017 baselines.

The standards have been expressed using two types of metrics: gram $CO_2$ per ton-mile and gallon of fuel per 1,000 ton-mile. The requirements for testing and compliance include both engine and vehicle standards. Engine manufacturers are subject to the engine standards. Testing is conducted over one test cycle: tractor engines are tested over the steady-state SET test and vocational engines are tested over the FTP transient test. The Phase 2 regulation introduced a new set of SET weighting factors, applicable only to GHG measurements (not applicable to pollutant emission measurements). The new weighting factors address the trend towards engine down-speeding.

Chassis manufacturers are subject to the vehicle standards. The vehicle standards compliance is typically determined based on a vehicle simulation model, called the *Greenhouse Gas Emission Model* (GEM), developed by the EPA specifically for the GHG/FE regulations. Phase 2 regulation introduced a number of changes to the GEM. Instead of using a chassis dynamometer as an indirect way to evaluate real-world operation and performance, various characteristics of the vehicle are measured and these measurements are used as inputs to the model. These characteristics relate to key technologies applicable to a given truck category—including aerodynamic features, weight reductions, tire rolling resistance, the presence of idle-reducing technology, vehicle speed limiters, and other factors.

**Combination Tractors**

Differentiated standards were adopted for several subcategories of combination tractors based on three attributes: weight class, cab type and roof height (Table 1). The regulations also define standards for tractors during the phase-in period: for MY 2014, MY 2021 and MY 2024. Engine-based standards must also be met by heavy heavy-duty (HHD) and medium heavy-duty (MHD) diesel engines used in tractors (Table 2). (Tables 1 and 2 are located on the following page.)

$CO_2$ emissions are tested on the same engine that is tested for pollutant emissions, typically the highest rated engine within an engine family. While this is the worst case rating for meeting pollutant emission standards, it is typically the rating with the lowest specific $CO_2$ emissions within the engine family.

| Table 1: Final Phase 1 (2017) and Phase 2 (2027) combination tractor standards | | | | | | |
|---|---|---|---|---|---|---|
| Category | EPA $CO_2$ Emissions | | | NHTSA Fuel Consumption | | |
| | *g/ton-mile* | | | *gal/1,000 ton-mile* | | |
| | Low Roof | Mid Roof | High Roof | Low Roof | Mid Roof | High Roof |
| Final Phase 1 Standards (2017) | | | | | | |
| Day Cab Class 7 | 104 | 115 | 120 | 10.2 | 11.3 | 11.8 |
| Day Cab Class 8 | 80 | 86 | 89 | 7.8 | 8.4 | 8.7 |
| Sleeper Cab Class 8 | 66 | 73 | 72 | 6.5 | 7.2 | 7.1 |
| Final Phase 2 Standards (2027) | | | | | | |
| Day Cab Class 7 | 96.2 | 103.4 | 100.0 | 9.44990 | 10.15717 | 9.82318 |
| Day Cab Class 8 | 73.4 | 78.0 | 75.7 | 7.21022 | 7.66208 | 7.43615 |
| Sleeper Cab Class 8 | 64.1 | 69.6 | 64.3 | 6.29666 | 6.83694 | 6.31631 |
| Heavy-haul Class 8 | 48.3 | | | 4.74460 | | |

| Table 2: Engine standards for engines installed in tractors (SET cycle) | | | |
|---|---|---|---|
| Category | Year | $CO_2$ Emissions | Fuel Consumption* |
| | | *g/bhp-hr* | *gallon/100 bhp-hr* |
| MHD Engines | 2014 | 502 | 4.93[a] |
| | 2017 | 487 | 4.78 |
| | 2021 | 473 | 4.6464 |
| | 2024 | 461 | 4.5285 |
| | 2027 | 457 | 4.4892 |
| HHD Engines | 2014 | 475 | 4.67[a] |
| | 2017 | 460 | 4.52 |
| | 2021 | 447 | 4.3910 |
| | 2024 | 436 | 4.2829 |
| | 2027 | 432 | 4.2436 |

* Equivalent NHTSA standards based on 10,180 g $CO_2$ per gallon of diesel
[a] Voluntary in MY 2014 and MY 2015.

### Trailers

The Phase 2 program introduced a new set of trailer standards effective in MY 2018. The final 2027 standards are shown in Table 3 (below).

The Phase 2 rule also includes $CO_2$/FE standards for partial-aero box vans, as well as design-based standards (tire rolling resistance level and pressure system) for non-box trailers and non-aero box vans. Both sets of standards are phased in over 2018-2021.

### Vocational Trucks

For Phase 1, this vehicle segment has been divided into three regulatory subcategories, Light Heavy (Class 2b through 5), Medium Heavy (Class 6 and 7), and Heavy Heavy (Class 8), consistent with engine classifications. In Phase 2, the standards were further differentiated depending on engine type (diesel, gasoline) and the duty cycle: urban, multi-purpose and regional. The final Phase 1 (2017) and Phase 2 (2027) vehicle standards are depicted in Table 4 (below) and Table 5, respectively.

Engine standards for light heavy-duty (LHD), medium heavy-duty (MHD), heavy heavy-duty (HHD) diesel engines and for heavy-duty gasoline engines are shown in Table 6. (Tables 5-6 are located on the following page.)

The EPA $CO_2$ emissions must be met over the engine's and vehicle's useful life. The useful life definitions for engines and for vehicles that use the respective engine categories are:

- MHDDE—185,000 miles/10 years
- HHDDE—435,000 miles/10 years

Additional references for more details on the regulations include:

- EPA, 2011. "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium and Heavy Duty Engines and Vehicles," US Environmental Protection Agency (EPA), Final Rule, Federal Register, 176(179), 57106-57513, http://www.gpo.gov/fdsys/pkg/FR-2011-09-15/pdf/2011-20740.pdf
- EPA, 2016. "Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium and Heavy Duty Engines and Vehicles—Phase 2," US Environmental Protection Agency (EPA), Final Rule, Federal Register, 81(206), 73478-74274, https://www.gpo.gov/fdsys/pkg/FR-2016-10-25/pdf/2016-21203.pdf.

https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-greenhouse-gas-emissions-and-fuel-efficiency: Final Rule for Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium and Heavy Duty Engines and Vehicles - Phase 2.

Table 3: Final (MY 2027) standards for full-aero box vans

| Category | | EPA $CO_2$ Emissions | NHTSA Fuel Consumption |
|---|---|---|---|
| | | *g/ton-mile* | *gal/1,000 ton-mile* |
| Dry Van | Long | 75.7 | 7.43615 |
| | Short | 119.4 | 11.7288 |
| Refrigerated Van | Long | 77.4 | 7.60314 |
| | Short | 123.2 | 12.10216 |

Table 4: Phase 1 final (MY 2017) vocational vehicle standards

| Category | EPA $CO_2$ Emissions | NHTSA Fuel Consumption |
|---|---|---|
| | *g/ton-mile* | *gal/1,000 ton-mile* |
| Light Heavy Class 2b-5 | 373 | 36.7 |
| Medium Heavy Class 6-7 | 225 | 22.1 |
| Heavy Heavy Class 8 | 222 | 21.8 |

| Table 5: Phase 2 final (MY 2027) vocational vehicle standards | | | | | | |
|---|---|---|---|---|---|---|
| Category | EPA $CO_2$ Emissions | | | NHTSA Fuel Consumption | | |
| | *g/ton-mile* | | | *gal/1,000 ton-mile* | | |
| | Urban | Multi-purpose | Regional | Urban | Multi-purpose | Regional |
| Vehicles with CI engines | | | | | | |
| Light Heavy Class 2b-5 | 367 | 330 | 291 | 36.0511 | 32.4165 | 28.5855 |
| Medium Heavy Class 6-7 | 258 | 235 | 218 | 25.3438 | 23.0845 | 21.4145 |
| Heavy Heavy Class 8 | 269 | 230 | 189 | 26.4244 | 22.5933 | 18.5658 |
| Vehicles with SI engines | | | | | | |
| Light Heavy Class 2b-5 | 413 | 372 | 319 | 46.4724 | 41.8589 | 35.8951 |
| Medium Heavy Class 6-7 | 297 | 268 | 247 | 33.4196 | 30.1564 | 27.7934 |

| Table 6: Engine standards for engines installed in vocational vehicles (FTP cycle) | | | |
|---|---|---|---|
| Category | Year | $CO_2$ Emissions | Fuel Consumption* |
| | | *g/bhp-hr* | *gallon/100 bhp-hr* |
| LHD Engines | 2014 | 600 | 5.89[a] |
| | 2017 | 576 | 5.66 |
| | 2021 | 563 | 5.5305 |
| | 2024 | 555 | 5.4519 |
| | 2027 | 552 | 5.4224 |
| MHD Engines | 2014 | 600 | 5.89[a] |
| | 2017 | 576 | 5.66 |
| | 2021 | 545 | 5.3536 |
| | 2024 | 538 | 5.2849 |
| | 2027 | 535 | 5.2554 |
| HHD Engines | 2014 | 567 | 5.57[a] |
| | 2017 | 555 | 5.45 |
| | 2021 | 513 | 5.0393 |
| | 2024 | 506 | 4.9705 |
| | 2027 | 503 | 4.9411 |
| HD Gasoline Engines | 2016 | 627 | 7.06 |
| * Equivalent NHTSA standards based on 10,180 g $CO_2$ per gallon of diesel<br>[a] Voluntary in MY 2014 and MY 2015. | | | |

# PRODUCTION FORECAST

**North America Class 8 Production**

| | 2017 | 2018 | 2019F | | | | 2019F | 2020F | | | | 2020F | 2021F | 2022F | 2023F | 2024F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Q1 | Q2 | Q3 | Q4 | | Q1 | Q2 | Q3 | Q4 | | | | | |
| Tractor | 176,584 | 237,404 | 64,943 | 68,922 | 67,589 | 54,983 | 256,437 | 45,817 | 40,551 | 38,978 | 37,645 | 162,991 | 184,324 | 205,265 | 243,190 | 159,450 |
| Truck | 79,006 | 87,047 | 24,415 | 24,216 | 22,030 | 17,921 | 88,581 | 21,180 | 18,746 | 18,019 | 17,403 | 75,348 | 79,293 | 86,522 | 99,650 | 63,200 |
| Total Vehicles | 255,590 | 324,451 | 89,358 | 93,138 | 89,619 | 72,903 | 345,018 | 66,997 | 59,297 | 56,998 | 55,048 | 238,340 | 263,617 | 291,787 | 342,840 | 222,650 |
| | | | | | | | | | | | | | | | | |
| Engine over 10L | 212,508 | 275,125 | 75,930 | 80,443 | 77,571 | 62,873 | 296,818 | 55,437 | 48,977 | 46,608 | 44,804 | 195,827 | 219,189 | 244,272 | 288,567 | 189,037 |
| Engine under 10L | 43,082 | 49,326 | 13,428 | 12,695 | 12,048 | 10,030 | 48,201 | 11,560 | 10,320 | 10,390 | 10,243 | 42,513 | 44,428 | 47,515 | 54,272 | 33,613 |
| Total Engines | 255,590 | 324,451 | 89,358 | 93,138 | 89,619 | 72,903 | 345,018 | 66,997 | 59,297 | 56,998 | 55,048 | 238,340 | 263,617 | 291,787 | 342,840 | 222,650 |
| | | | | | | | | | | | | | | | | |
| Engine over 10L % | 83.1% | 84.8% | 85.0% | 86.4% | 86.6% | 86.2% | 86.0% | 82.7% | 82.6% | 81.8% | 81.4% | 82.2% | 83.1% | 83.7% | 84.2% | 84.9% |
| Engine under 10L % | 16.9% | 15.2% | 15.0% | 13.6% | 13.4% | 13.8% | 14.0% | 17.3% | 17.4% | 18.2% | 18.6% | 17.8% | 16.9% | 16.3% | 15.8% | 15.1% |
| | | | | | | | | | | | | | | | | |
| Captive | 149,872 | 196,645 | 53,200 | 55,800 | 54,000 | 44,481 | 207,481 | 40,000 | 35,300 | 34,000 | 32,968 | 142,268 | 160,810 | 182,152 | 217,200 | 151,677 |
| Non-Captive | 105,718 | 127,806 | 36,158 | 37,338 | 35,619 | 28,422 | 137,537 | 26,997 | 23,997 | 22,998 | 22,079 | 96,071 | 102,807 | 109,635 | 125,639 | 70,973 |
| Total Engines | 255,590 | 324,451 | 89,358 | 93,138 | 89,619 | 72,903 | 345,018 | 66,997 | 59,297 | 56,998 | 55,048 | 238,340 | 263,617 | 291,787 | 342,840 | 222,650 |
| | | | | | | | | | | | | | | | | |
| Captive % | 58.6% | 60.6% | 59.5% | 59.9% | 60.3% | 61.0% | 60.1% | 59.7% | 59.5% | 59.7% | 59.9% | 59.7% | 61.0% | 62.4% | 63.4% | 68.1% |
| Non-Captive % | 41.4% | 39.4% | 40.5% | 40.1% | 39.7% | 39.0% | 39.9% | 40.3% | 40.5% | 40.3% | 40.1% | 40.3% | 39.0% | 37.6% | 36.6% | 31.9% |
| | | | | | | | | | | | | | | | | |
| Diesel | 251,362 | 320,886 | 88,383 | 92,113 | 88,644 | 71,997 | 341,137 | 66,047 | 58,372 | 56,073 | 54,155 | 234,647 | 259,837 | 287,937 | 338,530 | 218,557 |
| CNG/LNG | 4,228 | 3,565 | 975 | 1,025 | 975 | 906 | 3,881 | 950 | 925 | 925 | 893 | 3,693 | 3,780 | 3,850 | 4,310 | 4,093 |

**Classes 5-7 North America Production**

| | 2017 | 2018 | 2019F | | | | 2019F | 2020F | | | | 2020F | 2021F | 2022F | 2023F | 2024F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Q1 | Q2 | Q3 | Q4 | | Q1 | Q2 | Q3 | Q4 | | | | | |
| Class 5 | 90,081 | 96,712 | 22,080 | 25,400 | 22,090 | 22,410 | 91,980 | 21,500 | 23,500 | 21,250 | 21,771 | 88,021 | 88,799 | 91,467 | 94,414 | 92,909 |
| Classes 6-7 | 158,644 | 176,009 | 47,709 | 51,384 | 39,694 | 42,639 | 181,426 | 44,373 | 45,228 | 41,514 | 41,321 | 172,436 | 171,963 | 174,973 | 180,028 | 181,532 |
| Total Vehicles | 248,725 | 272,721 | 69,789 | 76,784 | 61,784 | 65,049 | 273,407 | 65,873 | 68,728 | 62,764 | 63,092 | 260,458 | 260,762 | 266,440 | 274,442 | 274,442 |
| | | | | | | | | | | | | | | | | |
| Class 5 % | 36.2% | 35.5% | 31.6% | 33.1% | 35.8% | 34.5% | 33.6% | 32.6% | 34.2% | 33.9% | 34.5% | 33.8% | 34.1% | 34.3% | 34.4% | 33.9% |
| Classes 6-7 % | 63.8% | 64.5% | 68.4% | 66.9% | 64.2% | 65.5% | 66.4% | 67.4% | 65.8% | 66.1% | 65.5% | 66.2% | 65.9% | 65.7% | 65.6% | 66.1% |
| | | | | | | | | | | | | | | | | |
| Diesel | 207,979 | 226,091 | 57,519 | 63,314 | 50,634 | 53,352 | 224,819 | 54,723 | 55,753 | 49,609 | 50,598 | 210,683 | 206,167 | 208,647 | 214,905 | 212,975 |
| Gas | 40,116 | 46,142 | 12,150 | 13,350 | 11,050 | 11,582 | 48,132 | 11,000 | 12,800 | 13,000 | 12,345 | 49,145 | 53,940 | 57,112 | 58,821 | 60,747 |
| CNG | 630 | 488 | 120 | 120 | 100 | 115 | 455 | 150 | 175 | 155 | 150 | 630 | 655 | 680 | 715 | 720 |
| Total Fuel | 248,725 | 272,721 | 69,789 | 76,784 | 61,784 | 65,049 | 273,407 | 65,873 | 68,728 | 62,764 | 63,092 | 260,458 | 260,762 | 266,440 | 274,442 | 274,442 |
| | | | | | | | | | | | | | | | | |
| Diesel % | 83.6% | 82.9% | 82.4% | 82.5% | 82.0% | 82.0% | 82.2% | 83.1% | 81.1% | 79.0% | 80.2% | 80.9% | 79.1% | 78.3% | 78.3% | 77.6% |
| Gas % | 16.1% | 16.9% | 17.4% | 17.4% | 17.9% | 17.8% | 17.6% | 16.7% | 18.6% | 20.7% | 19.6% | 18.9% | 20.7% | 21.4% | 21.4% | 22.1% |
| CNG % | 0.3% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.3% | 0.2% | 0.2% | 0.2% | 0.3% | 0.3% | 0.3% | 0.3% |

**Note: Data based on ACT August 2019 Outlook**

# NORTH AMERICA ON-HIGHWAY COMMERCIAL VEHICLE ENGINE OUTLOOK



2019 LAWRENCE R. KLEIN BLUE CHIP AWARD WINNER

Contributor to Blue Chip Economic Indicators and WSJ Economic Forecast Panel

**ACT Research Co. 2024**

www.actresearch.net