Welcome to the *North American On-Highway Commercial Vehicle Engine OUTLOOK* a quarterly publication prepared by Rhein Associates, Inc., with support by ACT Research. The report is designed to present historical trends, current activity and forecasts of engine demand in on-highway commercial vehicles. This forecast uses engine information from a variety of industry sources, with the overall economics and historical and forecast vehicle data provided by Americas Commercial Research Co. LLC. The engine trends, forecasts and in-depth analysis are provided by Rhein Associates, Inc.

This is the first issue of a comprehensive quarterly report that, through the year, will cover:

- Highlights and updates of current engine trends
- Latest information on engine regulations
- Powertrain component trends
- Overview of all commercial vehicle engine demand
- In-depth analysis and forecast of the engines in the heavy duty and medium duty commercial vehicle markets. The report starts with engine demand in each of the ACT Research commercial vehicle segments and expands each to include:
  - Engine type (diesel, gasoline, natural gas, other)
  - Displacement
  - Captive vs non-captive
  - Premium vs non-premium engines for Class 8

We trust you will enjoy our quarterly report and look forward to hearing from you.

THOMAS RHEIN, President  
Rhein Associates Inc.

KEN W. VIETH, Sr. Partner & GM  
ACT Research Co., LLC

Q2, May 2016
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• 98.5% of Class 8 vehicles...
• Class 8 production split...
• Captive engines gain...
• NG engine adoption is...
• Diesel dominates in...

N.A. ON-HIGHWAY CV ENGINE OUTLOOK

Rhein Associates, Inc.

Americas Commercial Transportation Research Co., LLC
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**OEM UPDATES**
- 2017 new and updated engines are now released to meet GHG and fuel economy regulations.
- Cummins announces its 2017...
- Detroit has new premium...
- Daimler to bring...
- International announces...
- Isuzu will update its...
- PACCAR adds...
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- EPA proposes increase in...
- CARB proposes stricter regulations for...
- Final GHG/fuel economy regulations…
- U.S. DOE announces...
- American Petroleum Institute (API) approves...
- Stronger emissions rules may restrict...

**MARKET ANALYSIS - FORECASTS**

**Heavy-Duty Vehicle (Class 8) Engines:**
- Diesel engines dominate…
- Non-premium engines (<10L) have...
- Class 8 production was split...
- Captive engines gain...
- Non-premium engines moving to...
- Captive share of non-premium engines stops...
- Straight trucks are projected to...
- Premium engine displacements...
- Natural gas engine adoption is...

**Medium-Duty Vehicle (Classes 5-7) Engines:**
- Diesel engines dominate MD vehicles...
2017 TRUCK DIESEL ENGINE CHANGES

All of the manufacturers of diesel engines for on-highway commercial vehicles have been focused on improvements to current products to meet 2017 federal GHG/fuel economy regulations. Meeting GHG (Greenhouse Gas) and fuel economy goals has resulted in the development of more efficient engines.

- Combustion improvements (fuel atomization, fire point, injection pressure, electronic controls)
- Better air control (more efficient turbocharger, higher pressure, improved air handling, more compact, faster response)
- Reduced parasitic losses (reduced friction, improved lube system)
- Exhaust treatment improvements (increased SCR – less DPF use, better materials, single canister catalyst – compact, less weight & less temperature loss)

The federal engine regulations for 2017 engines maintain the 2010 emissions regulations while adding GHG and fuel economy standards. The truck diesel engine manufacturers are able to upgrade their current diesel engine product lines to be more efficient by incorporating a number of changes.

CUMMINS INTRODUCES 2017 ENGINES

For medium-duty trucks, the B6.7, with a 200 to 325 HP, 520 to 750 lb-ft ratings range, is the latest generation of B-Series engines, with improvements to fuel economy and efficiency.

In heavy-duty trucks, Cummins offers the 2017 X15 in two distinct ratings groups – one for customers who need maximum pulling power and performance, and one that maximizes fuel economy, providing the lowest total operating cost.
### 2017 DETROIT PREMIUM ENGINES

Detroit premium engines (≥ 10L) will have revised horsepower and torque ratings in 2017.

<table>
<thead>
<tr>
<th>Horsepower</th>
<th>Torque (lb-ft)</th>
<th>Displacement (Liters)</th>
<th>RPM</th>
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<tr>
<td>350</td>
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<tr>
<td>410</td>
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<td>440</td>
<td>1,900</td>
<td>11.8</td>
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<td>460</td>
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<tr>
<td>480</td>
<td>1,696</td>
<td>11.8</td>
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### DAIMLER INVESTING IN ENGINES

Daimler will invest $375 million and create 160 new jobs in 2018, expanding the company's strategy of vertical integration. Daimler will invest $375 million and create 160 new jobs in 2018, expanding the company's strategy of vertical integration.

The DD5 will be available for order later this year in Freightliner Class 5/6 M2-106 trucks for pick-up and delivery applications with Allison 1000/2000HS transmissions only, but no PTO provisions will be available until the wider model range is released in 2018. Two power ratings will be available, a 210HP/575 lb-ft torque and a 230HP/660 lb-ft torque, with plans for additional ratings in 2018. The engine is claimed to have a 3% fuel economy advantage over competitive products. An integrated engine brake will be optional and the engine will use a one-box after-treatment system configured under the passenger step. The engines, with a B10 life of 375,000 miles, will have a 45,000-mile maintenance interval and use the Detroit™ Connect Virtual Technician® remote diagnostics service. The DD5, along with all other Detroit engines, will meet GHG17 standards early.

The DD8 is a 6-cylinder, 7.7L diesel variant of the DD5 with anticipated HP in the 235 to 350 HP range. The Detroit DT12 automated manual transmission used in heavy-duty trucks will also be assembled in Detroit resulting in a capital investment of $100 million and the addition of 170 new jobs.

### INTERNATIONAL TO OFFER CUMMINS L9

International will be using the Cummins L9 (8.9-liter) engine in DuraStar and WorkStar chassis to supplement the current Cummins ISB and Navistar N9 options (the Navistar DT engine is no longer available). Cummins claims the L9 offers the highest power density in its class. Reportedly the next generation will offer improved fuel economy.
The power ratings for the Cummins L9 range from 260 HP with 720 lb-ft to 380 HP and 1,250 lb-ft.

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Displacement</th>
<th>Weight</th>
<th>Horsepower</th>
<th>Torque</th>
<th>RPM</th>
<th>Lb-ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cummins L9</td>
<td>10.8L</td>
<td>0</td>
<td>355</td>
<td>2,200</td>
<td>1,250</td>
<td>11.8</td>
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<td>425</td>
<td>2,200</td>
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<td>430</td>
<td>2,200</td>
<td>1,550</td>
<td>11.8</td>
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</table>

PACCAR has started to produce the MX-11 10.8L diesel at its plant in Columbus, MS to expand its heavy-duty product range. The MX-11 has an output of up to 430 HP and 1,550 lb-ft of torque, complementing the MX-13 engine. PACCAR has already built 10,000 MX-11’s at its DAF plant in Europe (since 2013). It is available now in Kenworth and Peterbilt trucks.

VOLVO UPDATES D11 AND D13 FOR 2017

Volvo’s retooled 2017 D11 engine features a 2.2% fuel efficiency improvement versus the 2014 model. Other enhancements include: a two-piece valve cover, common-rail fuel system that helps boost fuel savings while quieting the engine, wave pistons that improve fuel/oxygen mix for cleaner burning, an assembled camshaft that reduces weight by 27 lbs., shim-less rockers, and a power boost to 425 HP. Production of the new D11 will start in January 2017.

Volvo’s revamped 2017 D13 engine offers a 2.5% fuel efficiency gain versus its 2014 predecessor, using the same new common-rail fuel system, wave pistons, and assembled camshaft as found in the 2017 D11. The new D13 will also have a two-speed coolant pump on XE models that boosts fuel economy by 0.5%. Volvo is also offering an extra 100 lb-ft of torque for the 455 HP version of this engine, increasing overall torque to 1,850 lb-ft. Production for the new D13 will begin in October 2016.

The company will also offer its D13 diesel with turbo-compounding, which can deliver as much as a 6.5% improvement in fuel efficiency when compared to the 2014 model year D13.
Targeted for availability in mid-2017, the turbo-compounding technology on the D13 recovers waste heat and transfers it back to the engine as usable power — as much as 50 additional HP. The engine is targeted for use in sleeper cabs that see a lot of time cruising at highway speeds, a duty cycle that is more conducive to efficiency.
EPA PROPOSES RENEWABLE FUEL CHANGES

The U.S. Environmental Protection Agency (EPA) proposed increases in renewable fuel volume requirements across all types of biofuels under the Renewable Fuel Standard (RFS) program. The proposed increases would boost renewable fuel production and provide for ambitious yet achievable growth.

The proposed volumes would represent growth over historic levels:

- Total renewable fuel volumes would grow by nearly 700 million gallons between 2016 and 2017.
- Advanced renewable fuel — which requires 50 percent lifecycle carbon emissions reductions — would grow by nearly 400 million gallons between 2016 and 2017.
- The non-advanced or “conventional” fuels portion of total renewable fuels — which requires a minimum of 20 percent lifecycle carbon emissions reductions — would increase by 300 million gallons between 2016 and 2017 and achieve 99 percent of the Congressional target of 15 billion gallons.
- Biomass-based biodiesel — which must achieve at least 50 percent lifecycle emissions reductions — would grow by 100 million gallons between 2017 and 2018.
- Cellulosic biofuel — which requires 60 percent lifecycle carbon emissions reductions — would grow by 82 million gallons, or 35 percent, between 2016 and 2017.

The Clean Air Act requires the EPA to set annual renewable fuel volume requirements for four categories of biofuels. By displacing fossil fuels, biofuels help reduce greenhouse gas emissions and help strengthen energy security. The EPA is proposing to use the tools provided by Congress to adjust the standards below the statutory targets, but the steadily increasing volumes in the proposal continue to support Congress’s intent to grow the volumes of the n’s ov ad pr A’s Th on sal pu

CARB PUSHES FOR STRICTER REGULATIONS

The California Air Resources Board’s (CARB) Proposed 2016 State Strategy for the State Implementation Plan (State SIP Strategy) released this week describes proposed measures needed to meet federal ozone and PM2.5 standards over the next 15 years. Among the proposed measures is a low-NOx engine standard to be developed between 2017 and 2019, with implementation starting in 2023. CARB’s goal is to introduce near-zero-emission engine technologies to lower oxides of nitrogen (NOx) emissions from on-road heavy-duty vehicles. CARB said it may also petition the EPA to establish new federal heavy-duty engine emission standards. Truck and engine makers have said in the past that striving for low NOx in diesels could conflict with federal efforts to reduce greenhouse gas emissions by increasing fuel economy.

"While U.S. EPA is reluctant in Phase 2 to push a low-NOx standard, the fact is that California mandates place great pressure on the feds to follow suit," says Joe Rajkovacz, spokesman for the Western States Trucking Association. "In my opinion, manufacturers would rather see a single national standard instead of needing to build two different engines."

The State SIP Strategy is part of the larger California Sustainable Freight Action Plan, a multi-agency effort unveiled in early May. The plan, drafted in

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### Renewable Fuel Volume Requirements for 2014-2018

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
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<tr>
<td>Cellulosic biofuel (million gallons)</td>
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<tr>
<td>Biomass-based diesel (billion gallons)</td>
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<tr>
<td>Advanced biofuel (billion gallons)</td>
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<tr>
<td>Renewable fuel (billion gallons)</td>
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*Proposed Volume Requirements*
CARB said its existing mobile-emissions regulations will reduce NOx emissions in 2031 by more than 50% from today’s levels. These current programs will also result in significant reductions in PM2.5 emissions. This will bring most of the state into attainment with EPA standards except for meeting ozone standards in the South Coast, and PM2.5 standards in the San Joaquin Valley. NOx is the primary component of the smog that plagues the Los Angeles area.

Improved aerodynamics and reduced rolling resistance result in reduced NOx output. However, engine efficiency improvements are a different story. Basically, as engine efficiency increases so does NOx, while less efficient engines have fewer NOx but higher PM. Reducing both NOx and PM to the levels being considered requires major changes in engine type/development and/or the combination of current technologies. Segments that could benefit include natural gas, DME (dimethyl ether), hybrids and electrics.

Part of the plan includes accelerating the implementation of medium and heavy-duty vehicle GHG emission standards (Phase 2) to 2023. Trailers, which are included in the GHG regulation in 2018, already are required by CARB.

The CARB proposal also includes:

- Additional requirements for vocational vehicle aerodynamics
- GHG emission reduction requirements for other trailer types, such as flatbed, tanker, container, and curtain-side
- New standards for low-emissions diesel, requiring fuel producers to sell steadily increasing volumes of LED until they comprise 50% of total diesel sales by 2031.
- Reduction in time that transport refrigeration units operate using internal combustion engines while parked at certain California facilities and other locations. Compliance options would include the use of commercially available hybrid electric TRUs, TRUs equipped with electric standby motors, and new cryogenic transport refrigeration systems.
- For the first time, California plans to address emissions from the long-haul transit haulers to the last-mile delivery trucks.

FINAL GHG RULES FOR HD TRUCKS DELAYED

The U.S. Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) issued a Notice of Data Availability (NODA), announcing that new information has been made available pertaining to the proposed Phase 2 heavy-duty greenhouse gas (GHG) and fuel efficiency rulemaking. The agencies have requested comments on the new information, which are due by April 1, 2016, an additional 30-days comments period means Phase 2 rulemaking will be delayed at least until late summer (expected in August 2016).

The EPA/NHTSA are soliciting comments on a number of issues, including:

- Data related to the potential stringency of the standards—additional powertrain data and aerodynamic test data; supplemental test data relating to drive cycles for vocational vehicles; and cycle average mapping data
- Certain revised test reports and a revised version of the greenhouse gas emission model (GEM) used in developing of the proposed standards and in demonstrating compliance with those standards
- Memoranda relating to applicability and implementation of the standard. These memoranda address potential requirements for selective enforcement audits and confirmatory testing related to GHG emissions and applicability of emission standards and...
REGULATORY ENVIRONMENT – RESEARCH & DEVELOPMENT

DOE ANNOUNCES SUPERTRUCK II INITIATIVE

Building on the successes of the SuperTruck initiative, the U.S. Department of Energy (DOE) announced SuperTruck II, an $80 million funding opportunity (subject to congressional appropriations) for research, development and demonstration of long-haul tractor-trailer truck technology.

The DOE launched its SuperTruck initiative in 2010. Vehicles developed under SuperTruck I are Class 8 combination trucks, commonly known as 18-wheelers, that increase tractor-trailer fuel, engine and drivetrain efficiency through the use of advanced technologies. SuperTruck II projects will research, develop and demonstrate technologies to improve heavy-truck freight efficiency by more than 100%, relative to a manufacturer’s best-in-class 2009 truck, with an emphasis on technology cost-effectiveness and performance.

Achieving Class 8 truck efficiency increases will require an integrated systems approach. SuperTruck II projects will utilize a variety of truck and trailer technology approaches, such as improvements in engine efficiency, drivetrain efficiency, aerodynamic drag, tire rolling resistance, and vehicle weight. No reference was made to the ultra-low NOx emission targets from heavy-duty engines that have been pursued by the California Air Resources Board.

The DOE also announced $12 million in selections for three projects focused on the research, development and demonstration of plug-in electric powertrain technologies for medium- and heavy-duty vehicles. The plug-in electric powertrain projects target a fuel economy improvement of 50%-100% in commercial Class 6 delivery trucks. The recipients of the awards are Robert Bosch LLC ($5 million), Cummins Corporate Research and Technology ($4.5 million) and McLaren Performance Technologies ($2.6 million).

API APPROVES NEW DIESEL OIL STANDARDS

The American Petroleum Institute (API) has approved two new diesel engine oil standards, API Service Categories CK-4 and FA-4. The new service categories improve upon existing standards by providing enhanced protection against oil oxidation and protection against engine wear, particulate filter blocking, piston deposits, and degradation of low- and high-temperature properties.

API category CK-4 of higher HTHS viscosity (3.5 cP) is backwards compatible with current engines designed for oils category CJ-4. Category FA-4 of lower HTHS viscosity of 2.9-3.2 cP—intended to reduce engine friction and provide fuel economy improvements—is not backward compatible with CJ-4.

API is now preparing to license engine oils with the new standards:

- API CK-4 and FA-4 will first appear in the API Service Symbol “Donut” on December 1, 2016. This delay in licensing allows marketers time to test their new formulations and ready them for market.
- Most truck manufacturers recommending API-licensed CJ-4 engine oils will likely recommend truck owners start using CK-4 oils as soon as
REGULATORY ENVIRONMENT – RESEARCH & DEVELOPMENT

STRONGER EMISSION RULES MAY RESTRICT REPURPOSED TRUCKS

Vertical integration among truck makers will likely extend into emissions and fuel-saving technologies in the future. This ultimately could limit the number of

Coming soon is the next step in phase one of the federal greenhouse-gas rule, which is to tighten the maximum legal amount of carbon dioxide output from a truck. The rule mandated an initial reduction of carbon dioxide emissions and improvement in mileage standards by 3%, from a 2010 baseline, by January 2014; then rises another 3% with the upcoming second step in January 2017. Beyond that, the EPA said the proposed Phase 2 standards, wth

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Total North American Class 8 truck production peaked in 2015 with ACT predicting lower demand in 2016 and 2017 followed by recovery and a pre-emission boom in 2019 and 2020 before a sharp downturn in 2021. Our analysis of Class 8 engine history and forecast shows trends in type, displacement and capacity in total for both premium and non-premium engines used in tractors and trucks. Emissions and fuel economy regulations have historically been the driving force for engine change and the 2017 to 2021 period is no exception.

**DIESEL DOMINATES CLASS 8 TRUCKS**

The Class 8 analysis centers on diesel engines as gasoline engines are not available in trucks of this size and OEM installed alternative fuel engines (natural gas) are currently only available from Cummins Westport in the ISL-G (8.9L) and ISX-12G (11.9L). Natural gas engines constitute less than 2% of the total engines used in Class 8 trucks and are discussed in a separate section at the end of the analysis.

**STABLE DEMAND FOR NON-PREMIUM ENGINES**

The Class 8 industry is characterized with the use of premium vs. non-premium engines (< 10L). Premium engines are those with displacements over 10L with specifications providing high horsepower and durability for operation up to maximum gross vehicle weights. Non-premium engines generally have lower power ratings, operate at lower gross weights and accumulate lower annual mileage and most often used in regional haul and vocational trucks. Non-premium engines under 10L are also used in Class 7 medium-duty trucks.

The relationship between premium and non-premium engines in Class 8 has remained relatively consistent with non-premium engines under 10L accounting for around 12% of total. There was a temporary blip in non-premium demand when Class 8 tractor demand fell in 2013. For the forecast period, demand for non-premium engines maintains stability but the pre-buy ahead of 2021 emission impacts depresses the share of non-premium engines in 2019 and 2020. In 2021, non-premium engines gain penetration in a depressed industry.

**TRUCK BUILD GAINS SHARE**

In the depressed market of 2010, straight trucks used primarily in vocational applications, were discussed in a separate section at the end of the analysis. Of older vocational trucks plus some impetus in regional short haul operations.

**CAPTIVE ENGINES GAIN VS INDEPENDENTS**

All OEMs have their own captive engines and it's been their policy to increase the usage of these engines, often in association with other powertrain components. This leads to more integrated truck designs with some significant user benefits, but the opportunity for the truck OEMs is the generation of captive after-market sales and profits in a thin margin industry. The OEM truck dealers have to invest in new OEM technologies and manpower to provide the level of customer support required, but dealers also share in the enhanced revenue stream.
MARKET ANALYSIS AND FORECASTS

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Captive</th>
<th>Non-Captive</th>
<th>Captive %</th>
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<tbody>
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<td>100</td>
<td>70.0%</td>
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<tr>
<td>2018</td>
<td>50</td>
<td>10</td>
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<tr>
<td>2019</td>
<td>50</td>
<td>10</td>
<td>22.0%</td>
</tr>
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</table>

Source: RA/NCT

N.A. Class 8 Non-Premium Engines by Size

<table>
<thead>
<tr>
<th>Year</th>
<th>Up to 7L</th>
<th>7 to 8L</th>
<th>8 to 9L</th>
<th>9 to 10L</th>
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<tbody>
<tr>
<td>2014</td>
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<td>2021</td>
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Source: RA/NCT

Dealers face less direct competition from independent dealers — the primary competition is increasingly limited to dealers with the same OEM franchise.

Cummins, which is the only independent engine supplier to the Class 8 market, has partnered with Eaton, the primary independent transmission supplier in heavy-duty trucks to provide integrated engine/transmission packages to compete more aggressively with the OEMs' own integrated powertrains. PACCAR and International prominently feature the Cummins-Eaton powertrain package to compete with Daimler and Volvo-Mack's integrated powertrains.

In 2014, captive engines accounted for 58% of the industry. Captive engines accounted for 62% in 2015 and is projected at over 67% by 2020. Despite the growth of in-house engines, Cummins, as an independent supplier, maintains a significant presence with its 9L, 12L, and 15L engines and a new 12L engine is anticipated for late 2017.

SMALLER DISPLACEMENT IN NON-PREMIUMS

Non-premium engines in Class 8 are used primarily in truck rather than tractor applications. Truck usage includes dump, municipal and refuse applications; tractors with non-premium engines are used in light regional haul especially food and beverage delivery. Nearly all trucks and tractors with non-premium engines use day rather than sleeper cabs.

Today Cummins and Navistar are the two primary suppliers. In the future, Daimler and Hino will offer engines in the non-premium Class 8 segment. The majority of non-premium engines used in Class 8 are from 8 to 9L capacity. The Cummins ISL/L9 engine dominates the segment and all major OEMs use this engine (International trucks is adding the L9 engine in 2016 CY for the first time), Cummins-Westport ISL-G has the same displacement. Hino will enter the Class 8 segment with a new sub 9-liter engine for trucks over 33,000 lbs. GVWR (currently Hino offers Classes 6 and 7 medium-duty conventional trucks). Engines from 9-10L capacity from Navistar are forecast to decline as production moves to the Cummins L9. Under 7L engines are used in only a few applications at the lowest Class 8 GVWRs.

Looking to the future, we expect the 7-8L category to grow with new engine introductions, although the 8-9L category will remain the largest segment. As there are relatively few engines available, truck manufacturer engine changes can make a significant impact.
MARKET ANALYSIS AND FORECASTS

CAPTIVES <10L DECLINE REVERSING

In 2010, captive engines held close to a 60% share of non-premium Class 8 engines. By 2015, volumes were diverted to non-captive engines, so captive share fell to 25% and probably will fall further through 2018. However, new engine introductions should reverse the decline. By 2021, a share of almost 30% is projected to be supplied by truck manufacturers’ own engines. Although captive non-premium engines are forecast to grow strongly, 30% penetration is significantly lower than the overall Class 8 penetration for captive engines.

CLASS 8 PREMIUM ENGINES

The chart lists the available premium diesel engines. OEMs are progressively moving to 2017 emission and later engines. All engine OEMs will make major changes to existing engine designs and some new engines will be added. Included is Daimler’s 10.7L engine that is available in Europe and is anticipated to come to North America as a competitive response to Volvo-Mack, PACCAR and Cummins. Cummins is also expected to move to a new sub-12L engine in late 2017.

The sub 12L capacity engines fill the need for lowest HP and torque applications with HP ranges from 310 up to 430; 12 to 14L 370 to 505 HP and the largest engines over 14L from 400 to 605 HP. 2017 ratings are being progressively released by OEMs and are used where applicable.

TRUCKS GAIN PROPORTION OF PREMIUMS

The majority of premium engines in Class 8 trucks are used in tractor applications, but straight trucks used in heavy vocational applications are an important sub-segment. Trucks have not benefited as much as tractors from the recent high replacement of the aging vehicles in use. But, as the tractor market declines in the short term, truck penetration should climb to 23% of total in 2017 from 17% in 2015. This also reflects the economic slowdown that favors trucks versus tractors. In 2021, the strong pre-buy of tractors leads to an increased penetration of trucks, although truck volume is forecast to decline.
LOWER DISPLACEMENT FOR PREMIUMS

Premium engines are divided into 3 engine displacement categories: 10 to 12L, 12 to 14L and over 14L. The highest volume category has historically been the over 14L segment, but that is changing and will continue to do so. In 2010 55% of premium engines were over 14L, falling to 51% by 2015. In contrast, the 12 to 14L group, with emphasis on more efficient, smaller displacement and lighter-weight engines, expanded from 40% to 44%, but the smallest category from 10 to 12L held steady at 5%.

The trend to smaller displacement engines continues through the forecast period and by 2021 the over 14L displacement engines are forecast to fall to 37%. This trend reflects customer needs for more fuel efficient, lighter weight trucks and expanded horsepower and torque ratings of 12 to 14L engines that more closely match traditional over 14L engines. All OEMs offer captive engines around 13L capacity assisting the growth of captive in-house vs. purchased engines.

Over the next five years, the 10 to 12L segment shows the largest increase in production and penetration, aided by introduction of new models. Until 2014 there were limited 10-12L engines available. Volvo-Mack has offered an 11-liter engine since 2006, with refuse trucks an important volume component; Navistar had an 11-liter engine for some years, although it was phased out by 2013. The interest in smaller displacement premium engines is increasing: PACCAR recently introduced its new MX-11, Cummins will add a new sub 12L engine next year and we expect Daimler to add a competitive entry based on an existing European design.

The 10-12L segment offers the prospect of improved fuel economy, reduced weight and some cost advantages. Prime targets include regional haul and lower mileage vocational haulers. The Cummins ISX-12G natural gas engine is also included in the below 12L category.

In straight trucks, there is a more even split between the three engine categories, the smaller sub-12L category shows sustained growth in the forecast period.

For tractors, the dominance of the largest displacement engines is gradually declining in favor of 12-14L engines and continues consistently through the forecast period. The 12-14L category is popular with major fleets and maintains its lead position through the forecast period.
The smaller sub 12L engines have made little impact thus far in tractors. However, additional new entries, HP and torque ranges that overlap the 12-14L engines, plus category inherent efficiencies of reduced weight and improved economy for some users, should help this engine size make steady headway. Over the next 5 years, growth is projected to over 10% of total premium tractor engines.

### CLASS 8 NG ADOPTION SLOWS

Production of natural gas powered trucks in Class 8 had been slowly increasing but paused in 2015 as a percentage of total production. Although the low diesel fuel price remains unfavorable for large scale adoption, users already committed to the fuel continue to buy. Many users who may have considered natural gas as a way to reduce fuel costs 2-3 years ago have remained with diesel and will need to see a significant price increase in diesel fuel for them to reconsider natural gas. Natural gas fueling infrastructure continues to grow but is not easily available in many parts of the country, although some committed natural gas fleets continue to expand their own fueling infrastructure.

Environmentally conscious customers, especially those with operations that allow a return to base each day remain the primary users – the refuse industry being the prime example.

The forecast predicts a slow growth in natural gas adoption up to just over 3% of Class 8 production by 2021. Cummins-Westport is the only provider of diesel engine based natural gas powered trucks. Note: other natural gas users including bus and medium-duty units are not included here.

The ISL9-G engines compete in the non-premium engine class up to 10L and up until 2013 was the high volume Class 8 natural gas engine but did not address higher HP/torque needs. An important development is the introduction of Cummins near zero emission engine for 2017.

The ISX12G expanded natural gas opportunities with increased HP and torque and ability to have an 80,000 lbs. GCWR capability allowing for wider application, especially in the tractor segment. Westport offered a natural gas version of the Cummins ISX15, but with low volume the engine was discontinued.
MEDIUM-DUTY CLASSES 5-7

The table on the following page lists the medium-duty engines including those used in Class 8 non-premium applications shown in the Class 8 application column. Anticipated new entries from Daimler (Detroit), GM Duramax, Hino and Isuzu are included.

For the medium-duty category Classes 5 through 7, Class 5 has recently been the growth segment with more stable demand in Classes 6&7.

Production of Classes 5-7 medium-duty trucks, school buses, chassis and motorhomes increased steadily from the depressed level of 2010 and by 2015 had almost doubled to 237,000 units. Truck chassis cabs constitute the largest proportion with over 70% of the total, followed by school bus chassis, RV motorhome and stripped chassis.

Unlike Class 8 trucks, the medium-duty forecast is for continued growth through 2020 to 271,000 units with a slight reduction in truck chassis cab production in 2018.

Lighter weight Class 5 trucks have grown in importance and accounted for over 36% of the Classes 5-7 medium-duty segment in 2015, however, the forecast is for Class 5 trucks to remain stable as a proportion of medium-duty trucks.

The majority of Class 5 products share components and configurations with lighter weight vehicles. In powertrain, many use engines and transmissions similar with light-duty rather than specific medium-duty powertrains used in Classes 6 and 7. A major distinction is the widespread use of gas engines in Class 5.

Diesel engines have dominated medium-duty production for many years, but since 2010 when diesel engines increased in price and complexity, gas engines began to gain ground. With many trucks driven in Class 5 by non-professional truck drivers, the advantage of a less complicated operating truck is important to some users. There are still a limited number of gasoline engines available in medium-duty and more could be added. Some gas engines are converted to alternative fuel use (although for this analysis are counted as gas engines). Cummins will add a natural gas powered 6.7L engine this year with school bus anticipated to be a user. Some ISL-G natural gas engines are used in Class 7, but overall adoption of natural gas engines in medium-duty trucks will remain limited.
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Future...
ENGINE DEFINITIONS

North America is defined as the United States, Canada and Mexico (or NAFTA)

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

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  - g
  - e

- A
  - c
  - tr

- F
  - c
  - g

- H
  - o
  - p
  - tr

- E
  - o
  - v
  - s
  - n

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.

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  - 1
  - G

- M
  - di
  - p
  - tr

- Li
  - ai
  - fe
  - tr

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 REGULATIONS TIMING

<table>
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<th>Level</th>
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<tr>
<td>1</td>
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<td>2</td>
<td>2002/2004</td>
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<td>3</td>
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<td>2010</td>
</tr>
<tr>
<td>5</td>
<td>2014-2017</td>
</tr>
<tr>
<td>6</td>
<td>2021/2024/2027 (proposed)</td>
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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

The current 2016 truck diesel engine emissions regulations are the same as 2010 with no changes in NOx regulation expected until 2021/2024:

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

The first U.S. GHG emission and fuel consumption standards for heavy- and medium-duty vehicles were adopted on August 9, 2011. The rule was jointly developed by the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA), DOT. NHTSA developed fuel standards and the EPA developed a GHG emissions program under the Clean Air Act. The GHG program includes CO2 emission standards, as well as emission standards for N₂O and CH₄, and provisions to control hydrofluorocarbon leaks from air conditioning systems.
GHG and FUEL ECONOMY

Initial regulations cover model years (MY) 2014-2018 with NHTSA fuel economy standards being voluntary in 2014-2015 MY to satisfy EISA lead time requirements. The affected medium- and heavy-duty fleet incorporates all on-road vehicles rated at a GVW ≥ 8,500 lbs., and the engines that power them. CO₂ and fuel consumption standards vary by vehicle configuration:

- Combination Tractors. For combination tractors (the semi-trucks that typically pull trailers), the adopted engine and vehicle standards begin in 2014 MY and achieve from 7% to 20% reduction in CO₂ emissions and fuel consumption by 2017 MY over the 2010 baselines. Differentiated standards were adopted for nine subcategories of combination tractors based on three attributes: weight class, cab type and roof height. (Table 1)

In addition to vehicle standards, engine-based standards must be met by heavy-heavy-duty (HHD) and medium-heavy-duty (MHD) diesel engines used in combination tractors. (Table 2 - MY 2014 fuel consumption standards are voluntary.)

- Vocational Trucks. For vocational vehicles, the engine and vehicle standards start in MY 2014 and achieve up to a 10% reduction in fuel consumption and CO₂ emissions by MY 2017. 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)—which is consistent with engine classifications. The respective vehicle standards are depicted in Table 3.

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 4. (MY 2014-2016 diesel fuel consumption standards are voluntary).

The major effects of the 2013-2017 regulations on engines has been:

- Lighter weight components
- More SCR/less EGR
- Tailored HP/Torque Curves
- Improved combustion efficiency
- Improved electronics
- Fuel systems enhancements
- Downsizing
- More emphasis/development on alternative fuels and power systems
### Table 1: Final (MY 2017) Combination Tractor Standards

<table>
<thead>
<tr>
<th>Category</th>
<th>Low Roof</th>
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### Table 2: Engine Standards for Engines Installed in Tractors

<table>
<thead>
<tr>
<th>Category</th>
<th>Year</th>
<th>CO2 Emissions</th>
<th>Fuel Consumption</th>
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<tr>
<td>MHD Engines</td>
<td>2014</td>
<td>502</td>
<td>4.93</td>
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<td>2017</td>
<td>487</td>
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<td>HHD Engines</td>
<td>2014</td>
<td>475</td>
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<td>2017</td>
<td>460</td>
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### Table 3: Final (MY 2017) Vocational Vehicle Standards

<table>
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<th>Category</th>
<th>EPA CO2 Emissions</th>
<th>NHTSA Fuel Consumption</th>
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<td>Light Heavy Class 2b-5</td>
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<td>Medium Heavy Class 6-7</td>
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### Table 4: Engine Standards for Engines Installed in Vocational Vehicles

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<th>Category</th>
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<th>CO2 Emissions</th>
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<td>2017</td>
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<td>HH Gasoline Engines</td>
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BEYOND 2017

The U.S. Environmental Protection Agency (EPA) and the Department of Transportation’s National Highway Traffic Safety Administration (NHTSA) have jointly proposed a national program that would establish a second phase of greenhouse gas (GHG) emissions and fuel efficiency standards for medium- and heavy-duty vehicles. Building on the success of the Phase 1 standards, the proposed Phase 2 program would cut GHG emissions by approximately 1 billion metric tons, conserve approximately 1.8 billion barrels of oil, and lower fuel costs by about $170 billion over the lifetime of the vehicles sold under the program.

The agencies are proposing new, more stringent standards for the same classes of heavy-duty engines that power combination tractors and vocational vehicles. The proposed CO2 and fuel consumption standards would start in MY 2021, increase incrementally in MY 2024, and phase in completely by MY 2027. For combination tractors and engines, the fully phased-in standards would achieve up to 24 percent lower CO2 emissions and fuel consumption compared to the Phase 1 standards including a 4.2% for engines. For vocational vehicles, including a wide variety of truck and bus types like delivery trucks, refuse haulers, public utility trucks, transit, shuttle, and school buses as well as emergency vehicles, and cement and dump trucks plus separate standards for emergency vehicles. The fully phased-in standards would achieve up to 16 percent reduction in CO2 emissions and fuel consumption relative to Phase 1. The Phase 2 program also includes proposed standards for trailers used with heavy-duty combination tractors. The fully-phased standards in 2021 MY would achieve up to 8 percent lower CO2 emissions and improved fuel consumption compared to an average MY 2017 trailer.

After a long comment period, the final regulations are expected to be issued in August 2016.
### North America Class 8 Production

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<tr>
<th>Year</th>
<th>Tractor Q1</th>
<th>Tractor Q2</th>
<th>Tractor Q3</th>
<th>Tractor Q4</th>
<th>Premium Engine (≥ 10L) Q1</th>
<th>Premium Engine (≥ 10L) Q2</th>
<th>Premium Engine (≥ 10L) Q3</th>
<th>Premium Engine (≥ 10L) Q4</th>
<th>Non-Premium (&lt; 10L) Q1</th>
<th>Non-Premium (&lt; 10L) Q2</th>
<th>Non-Premium (&lt; 10L) Q3</th>
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### Classes 5-7 North America Production

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### North America Class 8 Production Forecast

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N.A. ON-HIGHWAY CV ENGINE OUTLOOK