2019 Diesel Benefits Research

Final
August 2019
2019 Heavy Duty Objectives

- **Heavy Duty Benefits - Understand the benefits of New Technology Diesel Engines (NTDE) in the commercial vehicle fleet.**
  > Definition of New Technology Diesel
    - Diesel commercial vehicles that meet the near zero PM standard for model year 2007
    - Diesel commercial vehicles that meet the near zero NOx standard for model year 2010
      - These standards are cumulative reductions in PM and NOx
  > Definition of benefits:
    - PM reduction
    - NOx reduction
    - Fuel savings
    - GHG reduction
  > Benefits Research undertaking:
    - Nationwide: Model the NOx and GHG reduction and fuel savings nationwide that have accrued through the adoption of MY 2010 and newer diesel commercial vehicles
    - Nationwide: Model the PM reduction nationwide that have accrued through the adoption of MY 2010 and newer diesel commercial vehicles
    - Provide an estimate of the anticipated fuel savings and CO2 reduction, attributable to the adoption of more efficient diesel commercial vehicles that come with technology to meet Phase 1 & Phase 2 fuel economy and GHG regulations for commercial vehicles

- **Benefits in the context of other energy policies including but not limited to:**
  > GHG reduction of a wind farm or solar panel array the size of a certain acreage or state or share of installed capacity currently
  > Fuel savings the size of the SPR, Imported oil, or removing so many cars from the road for a certain number of months or years
  > NOx and PM reduction from removing so many cars from the road for a number of years
2019 Heavy Duty Objectives

- Provide benefits above for USA, CA, Northeast States, and West Coast individually.
  - Scenario modeling: Model the additional NOx, PM, GHG, and fuel savings under the current VIO and technology forecast through 2030.

- Benefits for individual vehicle owners: Based on available information on pre-2010 vehicles, generate an example for each key category of trucks listed above.
  - A new (Class 8, pick up and delivery, or vocational) is getting on average 8.5 mpg; an X percent improvement over a pre-2010 similarly equipped vehicle.
  - At an annual average mileage for this type of truck (example XXX,000 miles per year) This translates into XXXX gallons of annual fuel savings, and a savings of $$ at 3.50 a gallon diesel and YY at $4.00 gallon diesel and ZZ at $4.25 gallon diesel.
  - This annual fuel savings translates into X,XXX fewer tons of CO2 emitted, on average for each class of truck.
  - Provide NOx and PM savings
National HD Diesel Benefits
New technology diesel engines have reduced NOx and PM emissions by more than 95% over the last 25 years.

**U.S. Emission Standards – Heavy Duty Trucks (>8,500lbs GVW)**

<table>
<thead>
<tr>
<th>HD Emission Standard</th>
<th>NOx (g/bhp-hr)</th>
<th>PM (g/bhp-hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>10.7</td>
<td>0.6</td>
</tr>
<tr>
<td>1998-2007</td>
<td>4.0</td>
<td>0.1</td>
</tr>
<tr>
<td>2007-2010</td>
<td>2.0*</td>
<td>0.1</td>
</tr>
<tr>
<td>2011+</td>
<td>0.2</td>
<td>0.01</td>
</tr>
</tbody>
</table>

*Actual standard is NMHC*NOx with a 0.5g/bhp*hr maximum on NMHC
California lags the nation by 7% in share of heavy duty vehicles that are 2011MY and newer.

*Share of New Technology Heavy-duty Vehicles for Key States*
Over 50% of the 2018 heavy duty fleet are powered with new technology diesel engines built after 2006.

U.S. New Technology Diesel Engines (NTDE) in Operation – Heavy Duty

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
Selective catalytic reduction (SCR) technology used to meet 2010 emission standards has reduced fuel consumption by a conservatively estimated 3-4%.

U.S. Fuel Economy by Vehicle Class – Heavy Duty Trucks

<table>
<thead>
<tr>
<th>Class</th>
<th>Example Production Vehicle</th>
<th>VMT Range</th>
<th>2007 MPG Range</th>
<th>Average 2007 MPG</th>
<th>2010 MPG with SCR Range</th>
<th>Average 2010 MPG with SCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Ford F-450</td>
<td>30-35,000</td>
<td>7-12</td>
<td>8.8</td>
<td>7.3-12.5</td>
<td>9.2</td>
</tr>
<tr>
<td>5</td>
<td>Kenworth T170</td>
<td>30-40,000</td>
<td>6-12</td>
<td>8.0</td>
<td>6.3-12.5</td>
<td>8.3</td>
</tr>
<tr>
<td>6</td>
<td>Peterbilt Model 330</td>
<td>40-50,000</td>
<td>5-12</td>
<td>7.1</td>
<td>5.2-12.5</td>
<td>7.4</td>
</tr>
<tr>
<td>7</td>
<td>Kenworth T370</td>
<td>40-50,000</td>
<td>4-8</td>
<td>5.3</td>
<td>4.2-8.3</td>
<td>5.6</td>
</tr>
<tr>
<td>8</td>
<td>Freightliner Cascadia</td>
<td>110-140,000</td>
<td>4-7.5</td>
<td>5.2</td>
<td>4.2-7.8</td>
<td>5.4</td>
</tr>
</tbody>
</table>

Source: “Final Rulemaking to Establish Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles” RIA Table 1-1, EPA420-R-11-901
MOVES models vocations and prescribes a set of factors to roll up the emission levels to an aggregate HD GVW class:

<table>
<thead>
<tr>
<th>Vehicle Classification</th>
<th>Passenger Trucks</th>
<th>Light Commercial Trucks</th>
<th>Refuse Trucks</th>
<th>Single-unit Short-haul Trucks</th>
<th>Single-unit Long-haul Trucks</th>
<th>Motor Homes</th>
<th>Combination Short-haul Trucks</th>
<th>Combination Long-haul Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 3 Heavy-Duty Diesel Vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10,001–14,000 lb GVWR)</td>
<td>43%</td>
<td>57%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Class 4 Heavy-Duty Diesel Vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(14,001–16,000 lb GVWR)</td>
<td>10%</td>
<td>90%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Class 5 Heavy-Duty Diesel Vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(16,001–19,500 lb GVWR)</td>
<td>10%</td>
<td>90%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Class 6 Heavy-Duty Diesel Vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(19,501–26,000 lb GVWR)</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>72%</td>
<td>6%</td>
<td>7%</td>
<td>11%</td>
<td>3%</td>
</tr>
<tr>
<td>Class 7 Heavy-Duty Diesel Vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(26,001–33,000 lb GVWR)</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>72%</td>
<td>6%</td>
<td>7%</td>
<td>11%</td>
<td>3%</td>
</tr>
<tr>
<td>Class 8a Heavy-Duty Diesel Vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(33,001–60,000 lb GVWR)</td>
<td>0%</td>
<td>0%</td>
<td>2%</td>
<td>30%</td>
<td>2%</td>
<td>0%</td>
<td>35%</td>
<td>31%</td>
</tr>
<tr>
<td>Class 8b Heavy-Duty Diesel Vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(&gt;60,000 lb GVWR)</td>
<td>0%</td>
<td>0%</td>
<td>2%</td>
<td>30%</td>
<td>2%</td>
<td>0%</td>
<td>35%</td>
<td>31%</td>
</tr>
</tbody>
</table>

Source: "Updated Emission Factors of Air Pollutants from Vehicle Operations in GREET Using MOVES", Table A1, Argonne National Laboratory September 2013
In-use emission rates for 2010MY and beyond class 4-8 trucks has dropped by over 90% since 2007.

**U.S. In-use Emissions by Vehicle Class – Heavy Duty Trucks**

<table>
<thead>
<tr>
<th>Class</th>
<th>Example Production Vehicle</th>
<th>IHS Expected VMT Range</th>
<th>In-use NOx Emissions (g/mi)</th>
<th>In-use PM Emissions (g/mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Ford F-450</td>
<td>27,523</td>
<td>Pre-2007: 5.36</td>
<td>Pre-2007: 0.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2010+: 0.98</td>
<td>2010+: 0.010</td>
</tr>
<tr>
<td>5</td>
<td>Kenworth T170</td>
<td>27,523</td>
<td>Pre-2007: 5.36</td>
<td>Pre-2007: 0.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2010+: 0.98</td>
<td>2010+: 0.010</td>
</tr>
<tr>
<td>6</td>
<td>Peterbilt Model 330</td>
<td>37,584</td>
<td>Pre-2007: 12.64</td>
<td>Pre-2007: 0.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2007-2009: 3.56</td>
<td>2007-2009: 0.019</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2010+: 1.13</td>
<td>2010+: 0.016</td>
</tr>
<tr>
<td>7</td>
<td>Kenworth T370</td>
<td>37,584</td>
<td>Pre-2007: 12.64</td>
<td>Pre-2007: 0.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2007-2009: 3.56</td>
<td>2007-2009: 0.019</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2010+: 1.13</td>
<td>2010+: 0.016</td>
</tr>
<tr>
<td>8</td>
<td>Freightliner Cascadia</td>
<td>80,000</td>
<td>Pre-2007: 20.40</td>
<td>Pre-2007: 0.94</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2010+: 2.24</td>
<td>2010+: 0.025</td>
</tr>
</tbody>
</table>

**Methodology Details**

- Due to the various different engines used by heavy truck manufactures, the EPA made the heavy duty certification standards engine based. These engine based standards, rated in g/bhp-hr, are converted by EPA for use in modeling emissions of the fleet through the MOVES in-use emission modeling software.

- The emission rates shown (in g/mi) are based on the EPA’s modeling of the heavy duty fleet output necessary for the MOVES model.

- These factors, combined with the average emission rates used by EPA to model the heavy duty fleet, are utilized on the following pages to generate a fleet wide savings for new technology diesel engines operating in the U.S. today.

Methodology used to generate heavy-duty diesel engine benefits:

Inputs and Assumptions Provided by DTF/IHS Markit

Heavy-duty Methodology:
- IHS Markit MHCV forecast used for top-line sales projections. These, combined with a vehicle retirement curve, were used to create a vehicle parc in the United States from 2018-2030.
- Inputs from IHS Markit’s Reinventing the Truck (RTT) product were used to project powertrain splits/fuel type for 2020-2030.
- Additionally, inputs from RTT were used to project fuel economy gains in diesel vehicles. These projections are in-line with the EPA’s expected fuel economy improvements based on the “Phase 1 of Fuel Efficiency and GHG Emission Program for Medium- and Heavy-Duty Trucks”
- Lastly, VMT projections were based on RTT inputs combined with EPA projections of VMT for various classes

Output and Analysis of Data Provided by IHS Markit

Heavy-duty Methodology:
- Vehicle level savings for each model year by U.S. total and for selected states based on actual registrations and average savings over pre-2007 emission certification equivalent powertrains.
- These vehicle level savings are summed up to generate a cumulative savings to date for post-2007 emission certification level diesel powertrains.
- Only current emission standards are accounted for with respect to PM and NOx reductions
U.S. Heavy-duty Fleet Benefits
Diesel engine share of commercial vehicles are expected to show about a 5% reduction from 2010 in new vehicles by 2030.

Source: IHS Markit © 2019 IHS Markit
From 2011-2018 new technology diesel engines in 3-8 heavy duty trucks have saved ~126 million tonnes of CO₂.

Diesel Savings per Year – Heavy Duty Trucks – U.S. National

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
From 2011-2030 new technology diesel engines in 3-8 heavy duty trucks will have saved ~1.3 B tonnes of CO₂.

Diesel Savings per Year – Heavy Duty Trucks – U.S. National

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
From 2007-2018 new technology diesel engines in the U.S. have removed ~18 million tonnes of NOx from the atmosphere.

Diesel Savings per Year – Heavy Duty Trucks – U.S. National

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
From 2007-2030 new technology diesel engines in the U.S. will have removed ~73 million tonnes of NOx from the atmosphere.

Diesel Savings per Year – Heavy Duty Trucks – U.S. National

Total Cumulative Savings
73M tonnes NO$_x$
4M tonnes PM

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
Putting the numbers into perspective...

- Class 3-8 heavy-duty diesels introduced in **2007 through 2018** saved the American consumer:
  > 126M tonnes of CO₂
  > 12.4B gallons of diesel
  > 296M barrels of crude oil
  > 18M tonnes of NOx
  > 1M tonnes of PM

- These reductions are equivalent to:
  > Removing the CO₂ emissions from 26M light-duty vehicles from the road for one year – or making them 0 emission electric vehicles
    - NOx emissions from all light-duty vehicles for 6 years and PM for 33 years
  > The CO₂ emissions from the electricity used in 22M homes for 1 year
  > Carbon sequestration from 150M acres of forests for one year
    - This is an equivalent forest roughly the size Texas
  > Creating a wind farm with 27,000 turbines over 135,000 acres; roughly 4 times the size of Washington D.C.

- Class 3-8 heavy-duty diesels introduced in **2007 through 2030** are expected to save the American consumer:
  > 1.3B tonnes of CO₂
  > 130B gallons of diesel
  > 33.1B barrels of crude oil
  > 73M tonnes of NOx
  > 4M tonnes of PM

- These reductions are equivalent to:
  > Removing the CO₂ emissions from 276M light-duty vehicles from the road for one year – or making them 0 emission electric vehicles
    - NOx emissions from all light-duty vehicles for 26 years and PM for 130 years
  > The CO₂ emissions from the electricity used in 227M homes for 1 year
  > Carbon sequestration from 1.5B acres of forests for one year
    - This is an equivalent forest roughly 3/4th of the lower 48 states
  > Creating a wind farm with 275,000 turbines roughly covering the entire state of Delaware
Northeast States Heavy-duty Fleet Benefits

Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont
From 2011-2018 new technology diesel engines in 3-8 heavy duty trucks have saved ~12.5 million tonnes of CO$_2$ in Northeast States.

Diesel Savings per Year – Heavy Duty Trucks – Northeast States

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
From 2011-2030 new technology diesel engines in 3-8 heavy duty trucks will have saved ~131 million tonnes of CO₂ in Northeast States.

*Diesel Savings per Year – Heavy Duty Trucks – Northeast States*

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
From 2007-2018 new technology diesel engines in the U.S. have removed ~2 million tonnes of NOx from the atmosphere in Northeast States.

Diesel Savings per Year – Heavy Duty Trucks – Northeast States

Total Cumulative Savings
2M tonnes NOx
135k tonnes PM

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
From 2007-2030 new technology diesel engines in the U.S. will have removed ~7.6 million tonnes of NOx from the atmosphere in Northeast States.

Diesel Savings per Year – Heavy Duty Trucks - Northeast States

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
West Coast Heavy-duty Fleet Benefits
California, Washington, Oregon
From 2011-2018 new technology diesel engines in 3-8 heavy duty trucks have saved ~12.3 million tonnes of CO\textsubscript{2} in West Coast States.

Diesel Savings per Year – Heavy Duty Trucks – West Coast States

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
From 2011-2030 new technology diesel engines in 3-8 heavy duty trucks will have saved ~133 million tonnes of CO₂ in West Coast States.

Diesel Savings per Year – Heavy Duty Trucks – West Coast States

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
From 2007-2018 new technology diesel engines in the U.S. have removed ~1.8 million tonnes of NOx from the atmosphere in West Coast States.

Diesel Savings per Year – Heavy Duty Trucks – West Coast States

Total Cumulative Savings
1.8M tonnes NOx
123k tonnes PM

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
From 2007-2030 new technology diesel engines in the U.S. will have removed ~7.3 million tonnes of NOx from the atmosphere in West Coast States.

Diesel Savings per Year – Heavy Duty Trucks – West Coast States

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
California Heavy-duty Fleet Benefits
From 2011-2018 new technology diesel engines in 3-8 heavy duty trucks have saved ~8.6 million tonnes of CO$_2$ in California.

Diesel Savings per Year – Heavy Duty Trucks – California

Total Cumulative Savings
842M gallons
20M barrels
8.6M tonnes CO$_2$

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
From 2011-2030 new technology diesel engines in 3-8 heavy duty trucks will have saved ~92 million tonnes of CO$_2$ in California.

Diesel Savings per Year – Heavy Duty Trucks – California

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
From 2007-2018 new technology diesel engines in the U.S. have removed ~1.2 million tonnes of NOx from the atmosphere in California.

Diesel Savings per Year – Heavy Duty Trucks – California

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
From 2007-2030 new technology diesel engines in the U.S. will have removed ~5 million tonnes of NOx from the atmosphere in California.

Diesel Savings per Year – Heavy Duty Trucks – California

Based on IHS Markit HD class 3-8 registrations and vehicles in operation for the U.S.
Heavy-duty Diesel Vehicle Summary

• 55% of the 2018 heavy duty fleet are powered with new technology diesel engines built after 2006.
  > New technology diesel engines have reduced NOx and PM emissions by more than 90% over the last 25 years.
  > Savings from 2007-2018 vehicles in 2018:
    – ~18M tonnes NOx, or emissions from all light duty vehicles for 6 years
    – ~1M tonnes of particulate matter, or emissions from all light duty vehicles for 33 years

• 43% of all on-highway diesel engines in operation are built after 2010 and equipped with SCR emission control technology saving GHG and fuel.
  > This fuel savings equates to:
    – 12.4B gallons of diesel, average class 8 truck savings of ~$3,000/year
    – 296M barrels of crude oil, the entire strategic petroleum reserve for sweet crude
    – 126M tonnes of CO₂, a years worth of carbon sequestration from a forest the size of Texas
Thank You
New technology diesel engines in class 8 trucks save ~$3,350/year in fuel costs.

Class 8 Line Haul Savings from NTDE

<table>
<thead>
<tr>
<th>Savings to the new technology diesel buyer</th>
<th>Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average vehicle miles traveled</td>
<td>125,000</td>
</tr>
<tr>
<td>Fuel savings - gallons</td>
<td>960</td>
</tr>
<tr>
<td>Fuel savings - bbl</td>
<td>23</td>
</tr>
<tr>
<td>Fuel cost savings @$3.50/gal</td>
<td>$3,350</td>
</tr>
<tr>
<td>CO₂ savings – metric tonnes</td>
<td>9.75</td>
</tr>
<tr>
<td>NOₓ savings – metric tonnes</td>
<td>2.3</td>
</tr>
<tr>
<td>Particulate matter savings – kg</td>
<td>114</td>
</tr>
</tbody>
</table>

Source: EPA estimates for in-use distance based on MOVES 2014 data
Class 7 vocational trucks with NTDE save 3.4 tonnes of CO₂ per year.

Class 7 Vocational Savings from NTDE

<table>
<thead>
<tr>
<th>Savings to the new technology diesel buyer</th>
<th>Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average vehicle miles traveled</td>
<td>45,000</td>
</tr>
<tr>
<td>Fuel savings - gallons</td>
<td>340</td>
</tr>
<tr>
<td>Fuel savings - bbl</td>
<td>8</td>
</tr>
<tr>
<td>Fuel cost savings @ $3.50/gal</td>
<td>$1,200</td>
</tr>
<tr>
<td>CO₂ savings – metric tonnes</td>
<td>3.4</td>
</tr>
<tr>
<td>NOₓ savings – metric tonnes</td>
<td>0.5</td>
</tr>
<tr>
<td>Particulate matter savings – kg</td>
<td>30</td>
</tr>
</tbody>
</table>

Source: EPA estimates for in-use distance based on MOVES 2014 data
Pick up and delivery vehicles have achieved an 82% reduction in real world NOx emissions with new technology diesel engines.

Class 5 Vocational Savings from NTDE

<table>
<thead>
<tr>
<th>Savings to the new technology diesel buyer</th>
<th>Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average vehicle miles traveled</td>
<td>35,000</td>
</tr>
<tr>
<td>Fuel savings - gallons</td>
<td>175</td>
</tr>
<tr>
<td>Fuel savings - bbl</td>
<td>4</td>
</tr>
<tr>
<td>Fuel cost savings @ $3.50/gal</td>
<td>$600</td>
</tr>
<tr>
<td>CO₂ savings – metric tonnes</td>
<td>1.6</td>
</tr>
<tr>
<td>NOₓ savings – metric tonnes</td>
<td>0.15</td>
</tr>
<tr>
<td>Particulate matter savings – kg</td>
<td>15</td>
</tr>
</tbody>
</table>

Source: EPA estimates for in-use distance based on MOVES 2014 data