Medium-Duty Emissions and GHG from a Full-Line Manufacturer’s Perspective

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Diesel Combustion System Team Leader
Outline

• What is Medium Duty?
• Regulatory Landscape
• Technical Challenges / Research Opportunities
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• What is Medium Duty?
• Regulatory Landscape
• Technical Challenges / Research Opportunities
Medium Duty is not... passenger cars or SUVs.

...combination tractor-trailers.
<table>
<thead>
<tr>
<th>NHTSA</th>
<th>Emissions</th>
<th>GHG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Light-Duty</td>
<td>Light-Duty</td>
</tr>
<tr>
<td>2A</td>
<td>Light-Duty</td>
<td>8,500 lbs.</td>
</tr>
<tr>
<td>2B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Medium-Duty</td>
<td>HD Pickups &amp; Vans</td>
</tr>
<tr>
<td>4</td>
<td>Medium-Heavy</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Heavy-Duty</td>
<td>Vocational Vehicles</td>
</tr>
<tr>
<td>6</td>
<td>Medium-Heavy</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Heavy-Duty</td>
<td>Heavy-Heavy Combination Tractors</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Defining Medium-Duty is ... complicated.
Functional Definition: HD pickups / vans & vocational vehicles.
O8500 vehicles play essential roles in the community – hero to those most in need, an enabler of services & a driver of the economic engine.
Ford Medium Duty Vehicles & Powertrains

- Super Duty
- Transit
- E-Series
- Transit CC-CA
- O8500 Medium Duty / Commercial Truck

Engines:
- 6.7L V8 Diesel
- 3.7L V6 TIVCT
- 6.2L V8 Gas
- 3.5L V6 EcoBoost
- 6.8L V10 Gas
- 3.2L I5 Diesel
- 3.5L V6
- 3.7L V6
Body builders / modifiers provide an endless array of upfits to meet any unique vocational need.
Unlike light-duty, diesel is a large portion of today’s O8500 fleet.

Unlike heavy-duty, gasoline also plays a significant role in the O8500 fleet, particularly in HD Pickups and Vans.

Both advanced gasoline and diesel powertrains will be needed to address unique performance requirements.
Outline

• What is Medium Duty?
• Regulatory Landscape
• Technical Challenges / Research Opportunities
Research and Advanced Engineering Certification Pathways

**Chassis Certification**

- Vehicle assessment
- Regulated in g/mile
- HD Pickups & Vans (Class 2B and 3)

**Dyno Certification**

- Engine assessment
- Regulated in g/bhp-hr
- Vocational vehicles

Diverse set of vehicles usage drives two certification pathways in O8500 segment.
Substantial reductions in both NOx + NMOG and CO emissions will drive the need for new technology solutions.

### Tier 3 / LEV III Chassis Certification Emissions

#### Class 2B (8,500 – 10,000 mi GVWR)*

<table>
<thead>
<tr>
<th></th>
<th>NOx [g/mi]</th>
<th>NMOG [g/mi]</th>
<th>NOx + NMOG [g/mi]</th>
<th>CO [g/mi]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Today</td>
<td>0.2</td>
<td>0.143</td>
<td>0.343</td>
<td>6.4</td>
</tr>
<tr>
<td>SULEV</td>
<td></td>
<td></td>
<td><strong>0.170</strong></td>
<td><strong>1.5</strong></td>
</tr>
</tbody>
</table>

#### Class 3 (10,000 – 14,000 mi GVWR)*

<table>
<thead>
<tr>
<th></th>
<th>NOx [g/mi]</th>
<th>NMOG [g/mi]</th>
<th>NOx + NMOG [g/mi]</th>
<th>CO [g/mi]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Today</td>
<td>0.4</td>
<td>0.167</td>
<td>0.567</td>
<td>7.3</td>
</tr>
<tr>
<td>SULEV</td>
<td></td>
<td></td>
<td><strong>0.230</strong></td>
<td><strong>1.7</strong></td>
</tr>
</tbody>
</table>

*FTP75 tested at ALVW
The addition of the SFTP will drive the need for solutions that provide benefits over a much broader area of the engine map.
Work Factors = 0.75 \times (\text{Payload} + 500 \times 4\text{wd}) + 0.25 \times \text{Towing Capacity}

CO_2 \text{ obligation is a function of the vehicle’s ability to do work. CO}_2 \text{ requirements are expected to be very challenging in 2025.}
Emissions are a tiny fraction of what they have been historically. New technology will be needed to further reduce emissions.
Vocational vehicle will be subject to both engine and vehicle CO$_2$ standards.

### Engine Requirement

**Assessment: Heavy-Duty Transient FTP**

<table>
<thead>
<tr>
<th>Engine type</th>
<th>Engine CO$_2$ in 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/bhp-hr</td>
</tr>
<tr>
<td>Light-Heavy Duty Diesel</td>
<td>576</td>
</tr>
<tr>
<td>Medium-Heavy Duty Diesel</td>
<td>576</td>
</tr>
<tr>
<td>Heavy-Heavy Duty Diesel</td>
<td>555</td>
</tr>
<tr>
<td>Gasoline (starting in 2016)</td>
<td>627</td>
</tr>
</tbody>
</table>

### Vehicle Requirement

**Assessment: GEM Compliance Model**

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Vehicle CO$_2$ in 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/ton-mile</td>
</tr>
<tr>
<td>Light-Heavy Duty</td>
<td>373</td>
</tr>
<tr>
<td>Medium-Heavy Duty</td>
<td>225</td>
</tr>
<tr>
<td>Heavy-Heavy Duty</td>
<td>222</td>
</tr>
</tbody>
</table>

Up to 10% reduction in CO$_2$ required for vocational vehicles and their engines.
Competition

Population Density & Transportation Demand

Regulatory

Fuel Cost & Infrastructure

Affordability

Customer Expectations

Taxation

Broader Economy

Climate Change

Energy Security

Intense pressures for change (variable by region) have many calling for a revolutionary shift to reduce fuel consumption of vehicles.

Regulations are one of many elements that drive the O8500 Market.
• What is Medium Duty?
• Regulatory Landscape
• Technical Challenges / Research Opportunities
There is a broad area where research is needed to improve CO₂ – not just engine. Ranking of losses is application specific.
Advanced SI Technologies

Variable valve actuation, fuel injection technology, and advanced boosting are key enablers for further SI engine efficiency improvements.
Key enablers to CO₂ and emissions include technology advances in fuel systems, boosting, VVA, aftertreatment and controls.
• OBD is required to ensure that every emissions control device (i.e. EGR, FIE, SCR, DPF, etc.) is functional

• OBD thresholds are coming down:
  – New emissions standards
  – Lower OBD monitor multipliers

• Sensing technology limitations (e.g. PM sensors and NOx sensors)

• New devices for thermal management require new monitors

New emissions requirements and new technology create OBD challenges. Improved sensing technology and new monitors need to be developed.
Thermal management of aftertreatment will be needed to meet Tier 3 / LEV III emissions, and will come at the expense of CO$_2$. 

Too Cold

Active exhaust temperature (Tier 3)

Tier 2 base

No exhaust temperature maintenance
It is critical to find solutions that both improve efficiency and provide exhaust temperature consistent required aftertreament function.

- Shifting energy from losses to brake power will result in:
  - Lower BMEP/IMEP
  - Lower exhaust temperature
- Improving CO$_2$ will likely make aftertreament thermal management even more challenging
Limited gasoline engine downsizing potential for CO₂ due to Tier 3 / LEV III SFTP emission requirements.
Medium Duty Downsizing

Work Factors = 0.75 * (Payload + 500 * 4wd) + 0.25 * Towing Capacity

The GHG potential of downsizing in O8500 is less than Light-Duty due to the necessary connection between CO₂ and work factor.
Affordability favor common solutions across both certification pathways.
• Lowering CO₂ within emissions constrains will involve improvements throughout the vehicle

• As we develop low CO₂ engine technologies for medium duty, it is imperative to:

  1. Identify solutions where the energy balance is conducive to meeting criteria emissions

  2. Identify technologies that can provide benefits across different use cases to give customer value over a wide range of vocational applications

  3. Develop sensor technology and techniques needed to perform OBD with new emissions requirements and new technologies.
Ford is Committed to:

- Low CO₂ Emissions
- Affordable technology
- High volume solutions