Bonus Emission Reductions
The Role of Emerging HD Technologies in Achieving California’s Emission Reduction Goals
Reductions Needed in Both GHG & Criteria Pollutants

- Increasing regulator & manufacturer attention on GHG challenge
- NAAQS ozone non-attainment remains a challenge for 1/3 of the nation
- More than 80% of California’s population lives in ozone non-attainment areas
- Vehicle emissions contribute significantly to both challenges (e.g. >60% of NO\textsubscript{X} emissions & >40% CO\textsubscript{2})
Viewing the NO\textsubscript{X}-CO\textsubscript{2} Relationship as a “Trade-off”

Hampers Optimizing for Emission Reductions

The (outdated) story behind the “trade-off”

- Vehicle emissions of both CO\textsubscript{2} and criteria pollutants must be reduced
- Vehicle manufacturers have argued emission control technologies constrains ability to meet GHG targets because of a NO\textsubscript{X} - CO\textsubscript{2} “tradeoff”
  - Conventional emission controls can reduce vehicle efficiency – increasing CO\textsubscript{2} emissions
  - Some more efficient combustion systems (e.g. advanced timing, etc.) can lead to increased NO\textsubscript{X} emissions from the engine
  - Some desirable engine efficiency strategies (e.g. stop/start, turbochargers, EGR valves, etc.) reduce exhaust gas temperatures below optimal level for NO\textsubscript{X} conversion using current emission control technologies

Efficient Engine

Emission Control System (Earlier Technology)

- Increased NOx Exhaust
- Cooler Temperature Exhaust Gas
New Approaches Enable “Emission Reduction Bonus”

• Integrated combinations of technology can achieve simultaneous NO\textsubscript{X} and CO\textsubscript{2} emission benefits

• By aggressively controlling one pollutant (e.g. NO\textsubscript{X}), in an integrated suite of engine technologies, it is possible to capture otherwise unavailable emission reductions in other (e.g. CO\textsubscript{2}) emissions

• Technology innovators are discovering that, rather than tradeoffs, optimized combinations of NO\textsubscript{X} and efficiency technologies can deliver “bonus” emission reductions

• Advanced SCR – the now dominant NO\textsubscript{X} abatement technology – enables:
  – Engine efficiencies that improve fuel economy and reduce GHG emissions
  – Cold start NO\textsubscript{X} reductions even at lower exhaust temperatures
Optimizing the Entire Technology Palette Creates Bonus Emissions Reductions

Fuel Combustion Controls

Air Handling

Advanced Aftertreatment

Advanced Transmissions

Waste Heat Recovery

Electronic Controls
Positive Trends In Certified Engines

While continuously making commercial trucks more fuel efficient, diesel engine and truck manufacturers have also been making them dramatically cleaner, a significant accomplishment considering that increased fuel efficiency and lower emissions are near opposite and competing forces in diesel engine design. In fact, diesel vehicles manufactured after 2010 achieve an average five percent improvement in fuel efficiency, making them cleaner and more fuel efficient than ever before! Source: http://www.dieselforum.org/diesel-at-work/delivering-for-america
<table>
<thead>
<tr>
<th>Future Enabling Technology</th>
<th>NO\textsubscript{X} Benefit</th>
<th>CO\textsubscript{2} Benefit</th>
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<tbody>
<tr>
<td>SCR-COATED DIESEL PARTICULATE FILTER</td>
<td>Increased NO\textsubscript{X} conversion, improved light-off and improved low-temperature/cold start performance</td>
<td>Lower exhaust backpressure &amp; reduced size and weight of exhaust controls</td>
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<td>HIGH-POROSITY SUBSTRATE</td>
<td>Increased NO\textsubscript{X} conversion, enables advanced SCR solutions</td>
<td>Flexibility to reduce size &amp; weight of exhaust controls or reduce exhaust backpressure</td>
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<tr>
<td>EXHAUST GAS THERMAL MANAGEMENT</td>
<td>Ensure exhaust gases are at optimal temperature for NO\textsubscript{X} destruction</td>
<td>Enables greater use of engine efficiency strategies including lean burn, turbochargers, and EGR valve</td>
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<td>WASTE HEAT RECOVERY</td>
<td>Increases efficiency with no additional NO\textsubscript{X} emissions</td>
<td>Utilizes waste heat for drivetrain and other vehicle power/energy needs</td>
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<tr>
<td>ELECTRONIC ENGINE CONTROLS</td>
<td>Continuous optimization of exhaust control system based on duty cycle</td>
<td>Optimizes fuel combustion variables for maximum efficiency</td>
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<td>NO\textsubscript{X} STORAGE</td>
<td>Stores cold-temp NO\textsubscript{X} emissions until downstream components reach optimal temperature for NO\textsubscript{X} conversion</td>
<td>Allows greater use of temperature-reducing engine efficiency strategies including stop/start, advanced combustion control, turbochargers, and EGR valve</td>
</tr>
<tr>
<td>GPS-ENABLED EMISSION CONTROLS</td>
<td>Maximum NO\textsubscript{X} emission control when vehicle operates in non-attainment area</td>
<td>Maximum efficiency operation when vehicle operates outside of a non-attainment area</td>
</tr>
<tr>
<td>HYBRID &amp; ALTERNATIVE POWERTRAINS</td>
<td>Reduced exhaust from fossil fuel combustion</td>
<td>Reduced engine-out NO\textsubscript{X} and CO\textsubscript{2} emissions</td>
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Innovation Progressing

- Increased attention across the industry to technology development opportunities
- Accelerating experiences through strategic collaborative supplier partnerships
- Rapid advances in new technologies taking place

All technical and customer acceptance challenges must be addressed before a technology can be considered “proven”

- Cost
- Complexity
- Integration
- Optimization
- Dependability
- Size/space limitations
- New/additional fluids may be required
- New materials must be developed/refined
- Incomplete engineering
Future of Optimization

DOE Supertruck Program shows potential for even more dramatic advances in:

- **Optimization** [Energy management, hybridization, powertrain, parasitics]

- **Technology** [Engine and powertrain efficiency improvements, weight reduction, hybridization, automatic engine shutdown, accessory improvements]

- **Engine Efficiency** [Cummins and Daimler have achieved the 50% efficiency goal, Volvo and Navistar has demonstrated 48% engine efficiency and is testing 50% BTE technologies in component test rigs]
Cost

- Incremental cost of advanced NOX controls is estimated to be $500 per Class 8 HD on-road vehicle

- Cost per ton of additional NOX reduction from mobile sources remains far below costs of reduction required by existing stationary source regulations

- In areas with persistent non-attainment, additional mobile source emission reductions can be cost-effectively delivered by deploying NOX control on non-road vehicles in addition to on-road systems

- Four decades of experience show that mobile source emission reductions technologies:
  - Are cost-effective
  - Cost less then than anticipated (by some) when introduced
  - Cost less over time that when introduced
Summary

• Vehicle technologies can deliver additional, simultaneous CO$_2$ and criteria emission reductions.

• The NO$_x$ - CO$_2$ “tradeoff” trend has been reversed on engines that are certified and in-use since 2007.

• Technologies in development exceed capabilities needed to meet current standards – and are being engineered to address further CO$_2$ and criteria challenges simultaneously.

• Innovative technology and optimization strategies enable – rather than constrain – more aggressive NO$_x$ - CO$_2$ emission policies.

• Some technical and customer acceptance issues have yet to be addressed – but current widespread commercial use of key technology components greatly reduces risk.
Thank You

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