HD Truck and Engine Fuel Efficiency
Opportunities and Challenges Post EPA2010

Ning Lei
Advanced Technology, Navistar, Aug 4th, 2009
North America’s Largest Integrated Truck and Engine Manufacturer
Navistar’s Engine Products

- A world wide leader with a full range of Diesel engines for commercial vehicles
- #1 Engine Manufacturer in South America

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Model Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Americana Engines</td>
<td>I-4/I-6 100 - 320 hp &lt;br&gt; Complete line of 3L-7L products</td>
</tr>
<tr>
<td>MaxxForce™ 5 a</td>
<td>4.5L V-6 150 - 310 hp &lt;br&gt; For Class 4-5</td>
</tr>
<tr>
<td>MaxxForce™ 7 a Ford V8a</td>
<td>6.4L V-8 200 - 350 hp &lt;br&gt; HD diesel Pickup/Vansa</td>
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<tr>
<td>MaxxForce™ a DT Series 9/10a</td>
<td>7.6L/9.3L I-6 210 - 330 hp &lt;br&gt; Class 6-7 Truck and School Busa</td>
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<tr>
<td>MaxxForce™ a 11/13 a</td>
<td>11L/13L Big Bore I-6 310 - 475 hp &lt;br&gt; Class 8 Truck</td>
</tr>
<tr>
<td>MaxxForce™ a 15a</td>
<td>15L Big Bore I-6 450 - 550 hp &lt;br&gt; Class 8 Trucka</td>
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Coming

[Image of engine models]
HD Diesel Engine Industry Journey

Engine BTE 5

- **Emission Reduction:**
  - NOx: 96%
  - PM: 96%

- **40 ~ 42%**

- **DOE FE Target:**
  - 50%-55%

- **Injection P**
- Adv EGR
- Adv Cooling
- 2-stage turbo
- Turbocomp.
- NOx Aftertreatment

**Anticipated HD Engine FE Regulation**

**Time?**
We Have Come A Long Way

Diesel Engine In-Cylinder Emission

Core Combustion o Technology o

- Significant o advancement in In-o Cylinder combustion capability
- Total engine o technology o integration is the o key toward a o successful product
Clean and Efficient ICE Will be with us for long time

Key to Successful Commercialization

For Clean and Efficient Combustion
- Adaptive Combustion Technology
- High Injection Pressure
- Fuel opportunities
- Flexible Air & EGR Charging System
- Total Engine and Vehicle Cooling Thermal Management
- Smart Engine Controls & Sensors
- Variable Valve Technology
- Waste Heat Recovery
- Aftertreatment Advancement
- Powertrain Integration
- Hybridization & Electrification

Technology Integration to meet Customer Expectations at Cost, Quality, Timing, Reliability
Adaptive Combustion Control

Look beyond traditional combustion optimization

<table>
<thead>
<tr>
<th>NOx (ppm)</th>
<th>Smoke (FSN)</th>
<th>EGR%</th>
<th>BSEC (g/hp-hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>0.82</td>
<td>0.94</td>
<td>0.99</td>
</tr>
<tr>
<td>1.05</td>
<td>0.78</td>
<td>0.94</td>
<td>0.99</td>
</tr>
<tr>
<td>1.05</td>
<td>0.73</td>
<td>0.94</td>
<td>0.99</td>
</tr>
<tr>
<td>0.95</td>
<td>0.87</td>
<td>0.95</td>
<td></td>
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Cylinder-to-Cylinder Fuel “trim”

Cylinder-to-Cylinder IVC “trim”

IVC adjustment
MaxxForce 13L

- 475hp, 1700ft-lb torque
- CGI crankcase
- High injection pressure, 2200bar
- Advanced 2-stage EGR & Cooling
- 2-stage turbocharger
- Improved control
- Improved DPF
Heavy Duty Class 8 Long Haul Truck FE Study

- Road Speed
- Load Management
- Drive Management
- Longer trailer
- Advanced Truck-Cab
- Integrated Truck-Cab
- Parallel Hybrid
- Rankine Cycle
- Elec. Turbocompounding
- Combustion
- Mech Turbocompounding
- VVA
- Baseline

% Fuel Efficiency Improvements

*** Data from multiple source, NESCCAF, ICCT, Calstart
Aerodynamics plays a key role in truck's fuel efficiency.

LoneStar was designed with
- fuel efficiency as a top priority
- functionality & emotional appeal

LoneStar earned
- EPA SmartWay certification
- Truck of the Year award

LoneStar is projected to be 5 to 15 percent more fuel efficient than traditional classic trucks
"Fuel Economy benefit highly dependent upon drive cycle

"Hybrid Trucks are most efficient in city driving

"Greatest benefit from working trucks is idle engine off operation

Does not include ‘Well to Wheel’ considerations only diesel fuel consumed during test

80% reduction Stationary Operation
20% reduction On Highway
DOE Supertruck Program

- DOE latest solicitation for HD OEM on vehicle efficiency
- Total system approach to achieve 50% improvement
- Fuel efficiency improvement requirements; 20% engine + 30% vehicle
- Great opportunity for collaboration, advancing the technology and defining the path to future commercialization for high FE technology

![Modern Truck Fuel Economy Range]

<table>
<thead>
<tr>
<th>Source</th>
<th>Engine Loss ~60%</th>
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<tr>
<td>Class 8 truck energy audit from 21 CTP Roadmap, 2006</td>
<td>Updated Oct 2008</td>
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</tbody>
</table>
Challenges to Commercialization

- Product cost
- Technology maturity and complexity
- Supplier base readiness
- Product development time

Technology breakthrough

FE Gain and Cost

Cost, $

FE Gain, %

Time

Industry Collaboration
OEMs, fleets, and suppliers

University & Research lab
Thank you

DOE to bring all of us together