Step change in Fuel Efficiency: Eaton’s perspective

October 2012
Many parts of the value chain…
…fuel efficiency is the central challenge!

- Government
- Fleets
- CO2 emissions
- Freight efficiency
- Regulations
- Drivers
- Safety
- Technology
- Differentiation
- Costs
- Manufacturers
- Suppliers

© 2011 Eaton Corporation. All rights reserved
Technology: no silver bullet… future is in smart systems and deep integration

- Smart and fast shifting
- Look-Ahead
- V2V and V2I

- Automation

- Engine Downspeeding

- Engine Downsizing

- Advanced Combustion
- Systems Integration & Optimization

- Fuels

- Natural Gas
- Micro-turbines

- EV: PHEV, Fuel Cells,

- Electrification

- Waste Energy

- Waste Heat Recovery

- Hybridization

- Advanced Boosting

- Reduced loads
- Drag, Rolling resistance, Friction, smart accessories

- Route planning
- Road load management
Diesels, Trucks and Trends…

Downspeeding 101

- Lower Friction
- Lower Pumping
- Combustion Optimization

1.5-3% Fuel Economy / 100 rpm

CO2 regulations 101

- Phase 1 (2014/17)
  - 6-23% reduction in Fuel Consumption
  - Special incentives for Advanced Technologies
- Phase 2 (2018+)
  - TBD Reduction
  - Technology-Forcing

Trends

<table>
<thead>
<tr>
<th>Vehicle Speed</th>
<th>-Fuel -Productivity</th>
<th>More Trucks!</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Speed</td>
<td>-Fuel -Driveability</td>
<td>High-Performance Automation</td>
</tr>
<tr>
<td>Engine Displacement</td>
<td>-Fuel -Driveability</td>
<td>Supercharging VVA</td>
</tr>
</tbody>
</table>
Downspeeding saves fuel but increases shift density

High-Performance Transmissions Enable Downspeeding Gains
Advanced boosting

HD Diesel Supercharger
• Instant boost
• Eliminates turbo lag
• Turbo optimized for steady conditions

Fuel economy with matched performance
• 22% 0-35 mph accel
• 2.3% line haul
• 5.4% HHDDT
• 16.7% FTP 72
What about Class 2b – 3?

- Significant fuel consumption improvement
- Electrical boosting
- Start-Stop
- Up to 50% engine downsizing
Efficient Variable Valve Actuation

**Downspeeding**
- Loss of engine brake capacity

**Downsizing**
- Cylinder deactivation

**Multi-stroke cycles**
- Added/Lost motion
- Cam-less
- Active timing control
Energy Recovery

Affordable Hybrids

Challenge: Get to 3 year payback from saved fuel
- State of art transmissions
- Small e-machines run in efficiency sweetspot
- Novel architecture

Waste Heat Recovery

Challenge: compact, simple, cost effective systems?
- Large heat exchangers vs. aerodynamics
- **Expander** efficiency vs. high speed machine complexity
MD and Bus: Ripe for Innovation!

**Electrification**
- Efficient EV drivetrains
- Rapid charging
- Fuel cells and micro turbines
- High Voltage Distribution

**Hybrids**
- Affordable solutions
- Scalability is key
- Advanced controls to reduce battery needs

**Drivelines**
- Efficient
- Automated
Advanced automation makes every driver a best driver

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>LPM On</th>
<th>Delta (%)</th>
<th>Compensated</th>
<th>Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>MPG</td>
<td>6.06</td>
<td>6.28</td>
<td>+3.5</td>
<td>Southfield – Ann Arbor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+5.3%</td>
<td>45,000 lbs</td>
</tr>
<tr>
<td></td>
<td>Avg Speed</td>
<td>52.42</td>
<td>51.40</td>
<td>-2.0</td>
<td></td>
</tr>
<tr>
<td>Test 2</td>
<td>MPG</td>
<td>6.59</td>
<td>6.66</td>
<td>+1.0</td>
<td>Detroit – Toledo</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+2.5%</td>
<td>(10 miles)</td>
</tr>
<tr>
<td></td>
<td>Avg Speed</td>
<td>59.55</td>
<td>61.24</td>
<td>+2.8</td>
<td>75,000 lbs</td>
</tr>
</tbody>
</table>

Expected average >4% mpg improvement across the fleet
Winning team: Government and Industry partnerships