Workshop Series on Transport and Climate:
July 24, 2013

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Cummins Inc.

Diversified Global Power Leader – Four Complementary Businesses

- World’s largest independent diesel engine manufacturer
- Over 1 million engines per year
- Customers in over 190 countries and territories
Duty Cycle and Application Complexity
Efficiency Optimisation Opportunities

- **Combustion Optimisation**
  - Advanced combustion and duty cycle optimisation
- **Aftertreatment efficiency improvement**
  - Manage de-activation and aging
- **Reduced friction & Parasitics**
- **Cycle Efficiency Management**
  - Optimize overall “cycle efficiency”
  - Advanced integration of telematics solutions
- **Powertrain optimization for fuel economy**
  - Rating & torque curve matching with final drive & transmission options
Combustion Improvements

- **Combustion CFD**
  - Combustion simulation to determine piston bowl & injector spray angle for increased CR configuration

- **Increased Compression Ratio**
  - Improved engine efficiency
  - Ideal for India applications with low HP ratings
SCR catalyst deactivation / aging

Deactivation mechanisms under nominal conditions:

1. Hydrothermal
2. Sulphur deactivation (SO$_3$)
3. Low temperature water interaction
4. Hydrocarbons
5. Others

- Understanding of deactivation mechanisms critical to sizing and robustness for maximum efficiency
Mechanical efficiency improved

- Improvements witnessed across speed and load map
  - Greatest efficiency improvements in the lower load portions of map

~30% reduction
Cycle Efficiency Management

- Cycle Efficiency Management systems can provide:
  - Fuel economy improvements *beyond the flywheel*
  - Fleet owners with tools to manage the fuel economy of their fleet
  - Operators with the ability to manage the trade off for performance and fuel economy

- Systems are estimated to provide up to an 8% improvement in fuel economy when fully utilized.

- Further opportunities evolve as the system is developed
## Cycle Efficiency Management: Sample Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
<th>Benefit</th>
<th>Inputs</th>
<th>Map</th>
<th>AMT</th>
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</thead>
<tbody>
<tr>
<td>Predictive Cruise Control</td>
<td>Dynamically adjusts vehicle speed</td>
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<tr>
<td>Operator Cost Management</td>
<td>Optimizes total cost of operation</td>
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<tr>
<td>Transient Torque Management</td>
<td>Manages available torque</td>
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<tr>
<td>Vehicle Deceleration Management</td>
<td>Provides shift recommendations</td>
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<tr>
<td>Vehicle Coasting Management</td>
<td>Manages transmission</td>
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</table>

• = Required by Feature  
0 = Availability Further Enhances Feature Performance
Further Feature Optimisation

Increasing Functionality

Increasing Complexity

Base Engine

Basic S/S

Mid Level S/S

Integrated Alternator

Mild Hybrid

Advanced S/S + MG based LV or HV

"Mild" Electrification Spectrum

3-5% Fuel Consumption benefit

Improved NVH, bearing wear, torque response and emissions; improved FC (~1%), accessories available during engine off

S/S function only, accessory needs met with engine restart or shutdown inhibit

Fewer belts, improved reliability/durability, improved FC (~2.5%), higher power for vehicle loads

Basic S/S + higher speed cranking, likely

Improved FC (~1%), improved performance

"Mild" Electrification Spectrum
Alignment With A Long Term Vision Of Gradual Electrification

- Start stop
- Energy capture
- Integrated power source (super alternator)
- Integrated starter generator
- Parallel full hybrid
- Accessory integration

- Less than 5 years?
- More than 10 years?

Passenger cars focus

Increased functionality vs. Increasing Complexity

- Basic
- Start stop with braking energy capture
- Integrated power source
- Integrated starter generator
- Parallel full hybrid
- Accessory integration

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India Roadmap....

- Criteria emissions
  - Stable legislation and clear implementation timeline
  - One Country, One Fuel, One Norm
  - Full enforcement

- More focus on Fuel consumption and CO$_2$ reduction
  - Separate engine and vehicle standards
  - Lead-time, clarity and certainty for efficiency improvements and technology development

“Level Playing Field for All”
India Roadmap….Further Opportunities

- Government, Industry & University collaboration?
  - Aligned goals for a “clean India vision”
  - Target critical areas (Cities?)
  - Structured framework
  - “Super Bus” programme (Similar to US DOE sponsored “Super Truck” programme)
Thank You