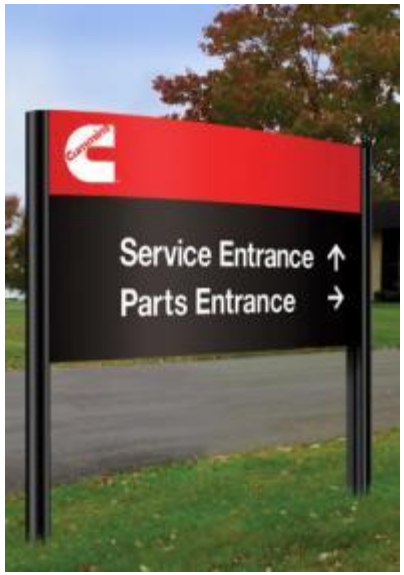
CENTRE FOR SCIENCE AND ENVIRONMENT

Workshop Series on Transport and Climate:
July 24, 2013

Paul Sowerby



Cummins Inc.

Diversified Global Power Leader – Four Complementary Businesses

Engines

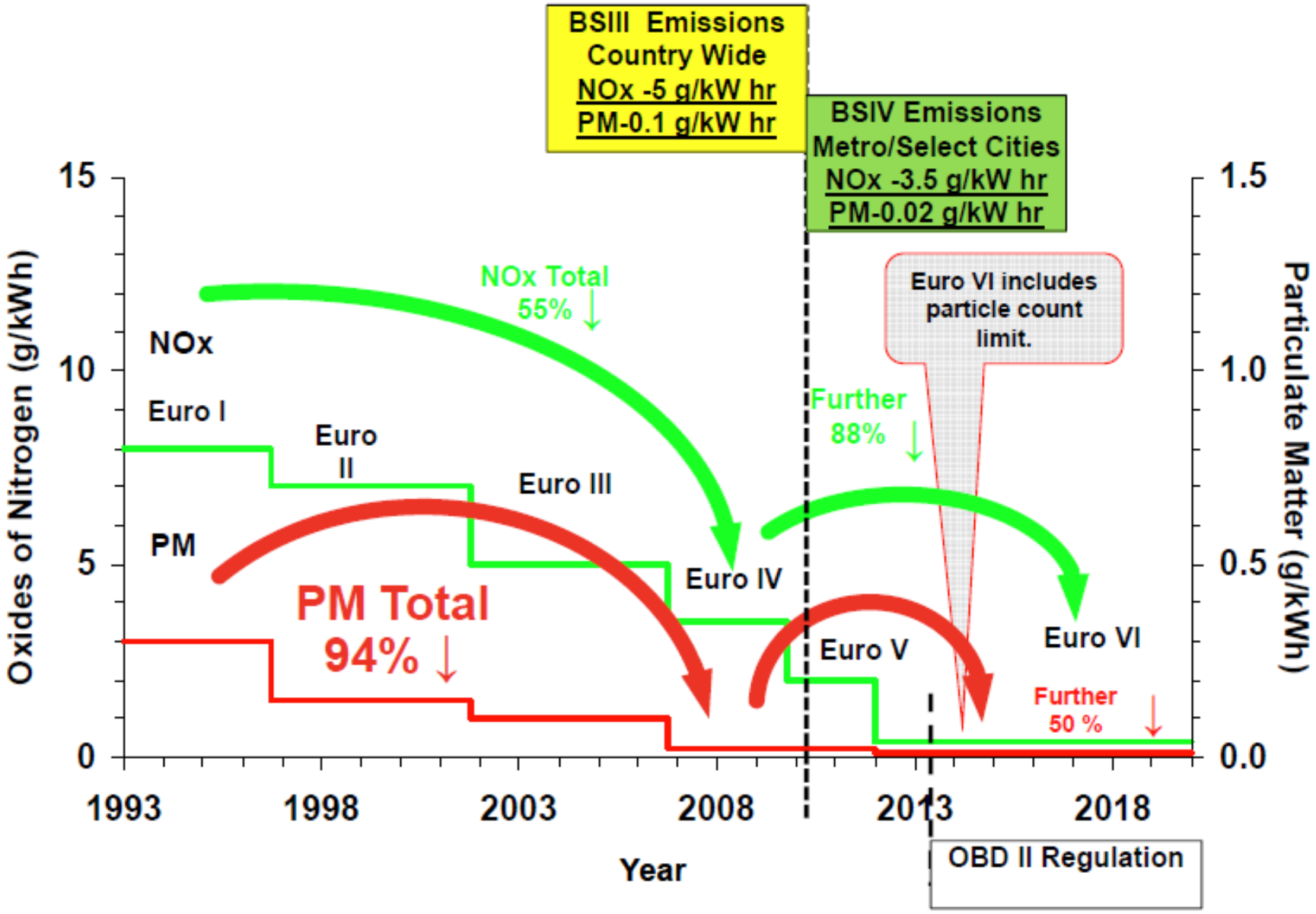
Power Generation

Components

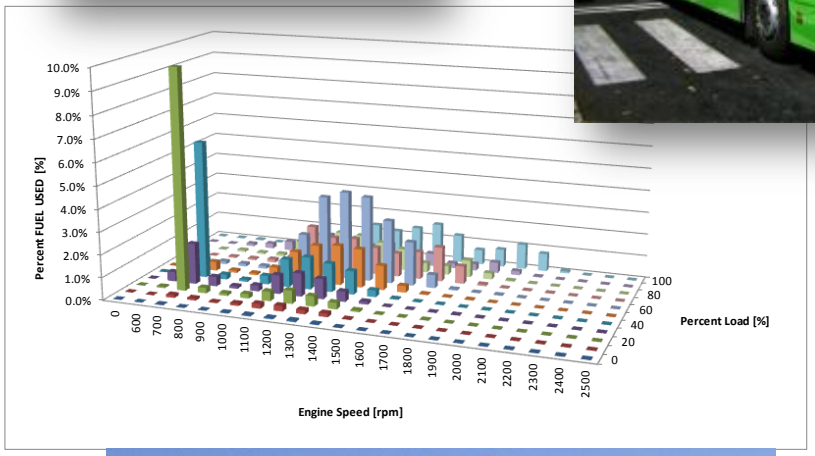
Distribution

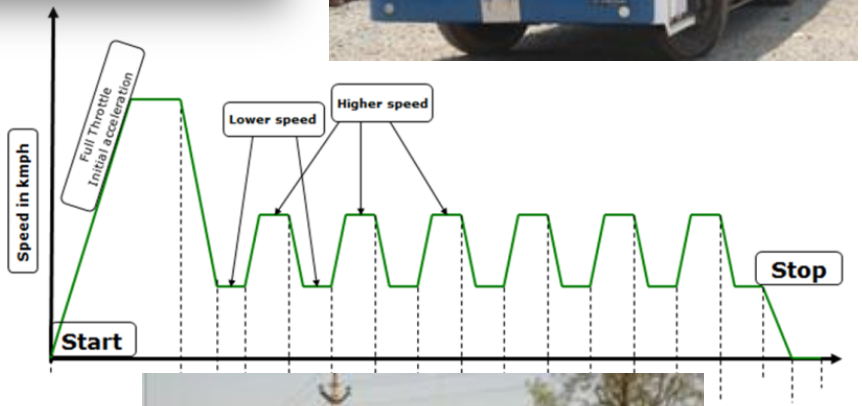
· World's largest independent diesel engine manufacturer ·
· Over 1 million engines per year ·
· Customers in over 190 countries and territories ·

Global Emissions Road Map



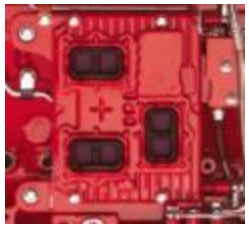
Duty Cycle and Application Complexity





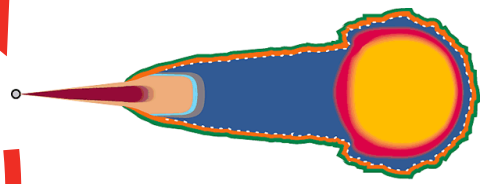
Technologies Meeting Emissions Standards

Filtration and Diesel Exhaust Fluid



Electronic Controls

Aftertreatment System



Combustion Technology

Turbochargers

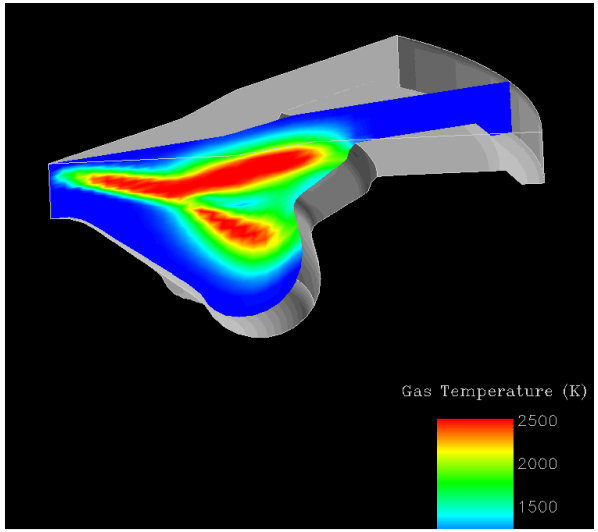
Fuel Systems

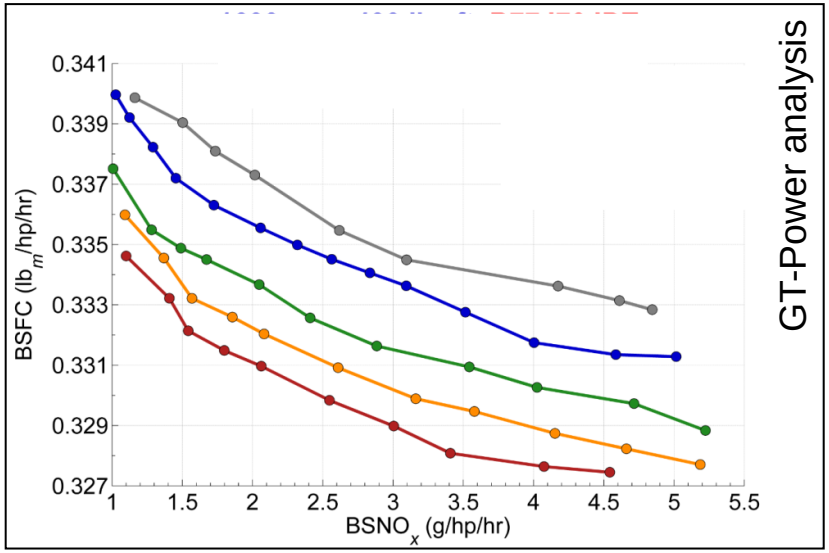
Efficiency Optimisation Opportunities

- 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



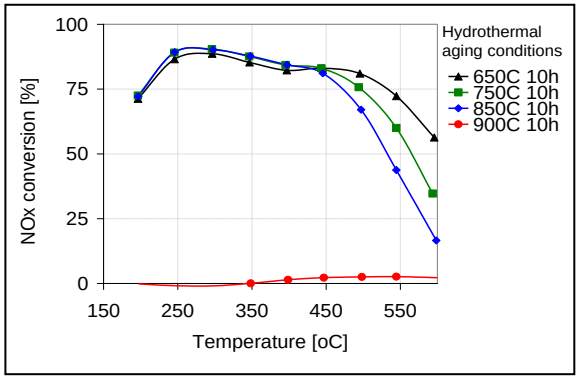


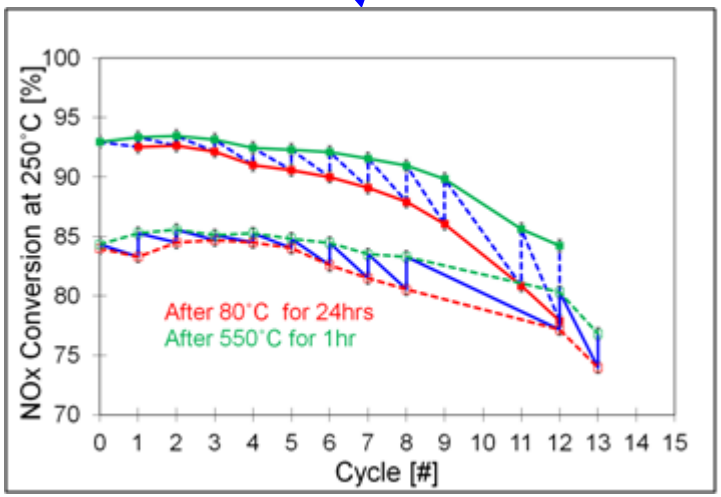
- Increased Compression Ratio
  - Improved engine efficiency
  - Ideal for India applications with low HP ratings

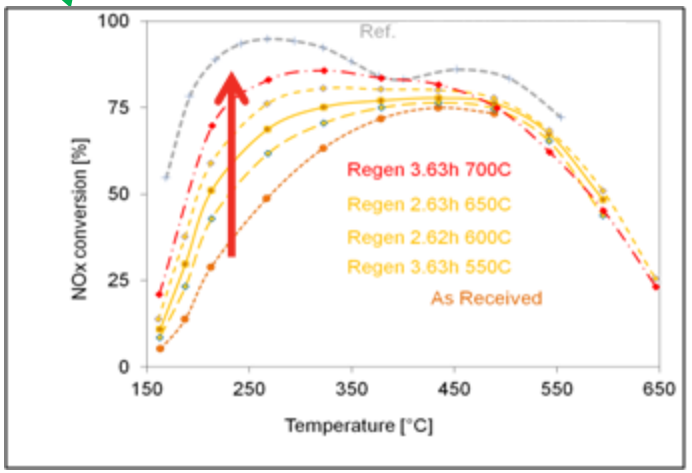
SCR catalyst deactivation / aging

Deactivation mechanisms under nominal conditions:

1. **Hydrothermal**
2. **Sulphur deactivation (SO_3)**
3. **Low temperature water interaction**
4. Hydrocarbons
5. Others

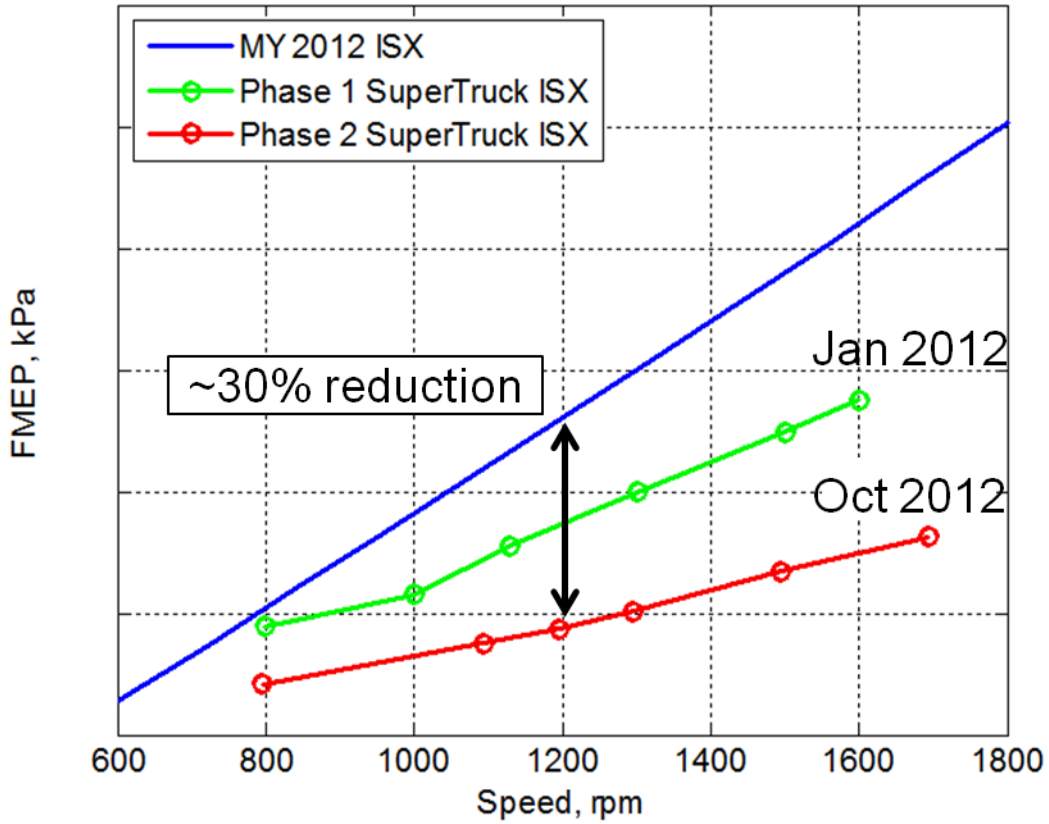






- Understanding of deactivation mechanisms critical to sizing and robustness for maximum efficiency

Engine Friction & Parasitic Reduction



Mechanical efficiency improved

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

Cycle Efficiency Management

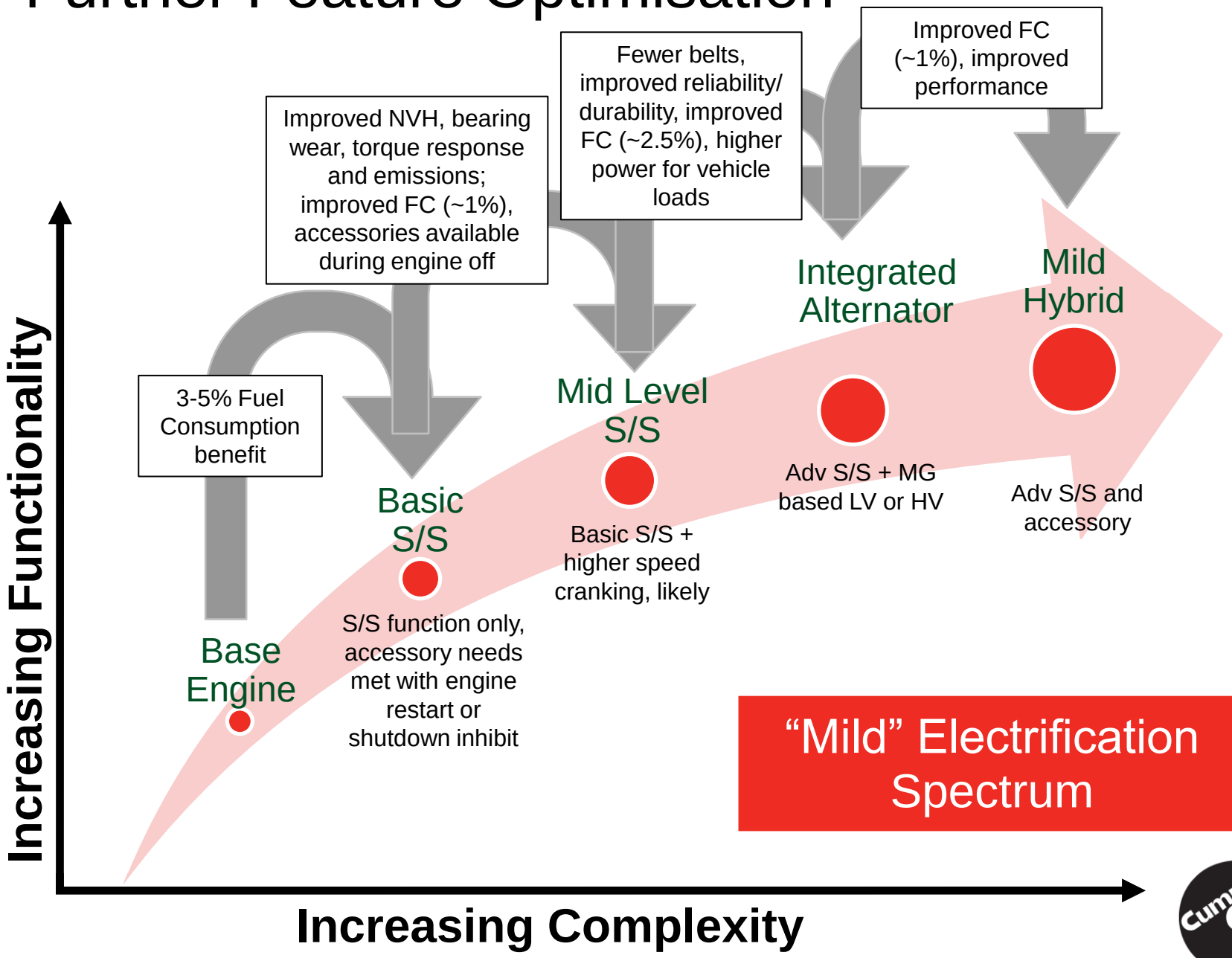
- Cycle Efficiency Management systems can provide:
  - Fuel economy improvements *beyond the flywheel*
  - Fleet owners with tools to manage the fuel economy of their fleet
  - Operators with the ability to manage the trade off for performance and fuel economy
- Systems are estimated to provide up to an 8% improvement in fuel economy when fully utilized.
- Further opportunities evolve as the system is developed

Cycle Efficiency Management: Sample Features

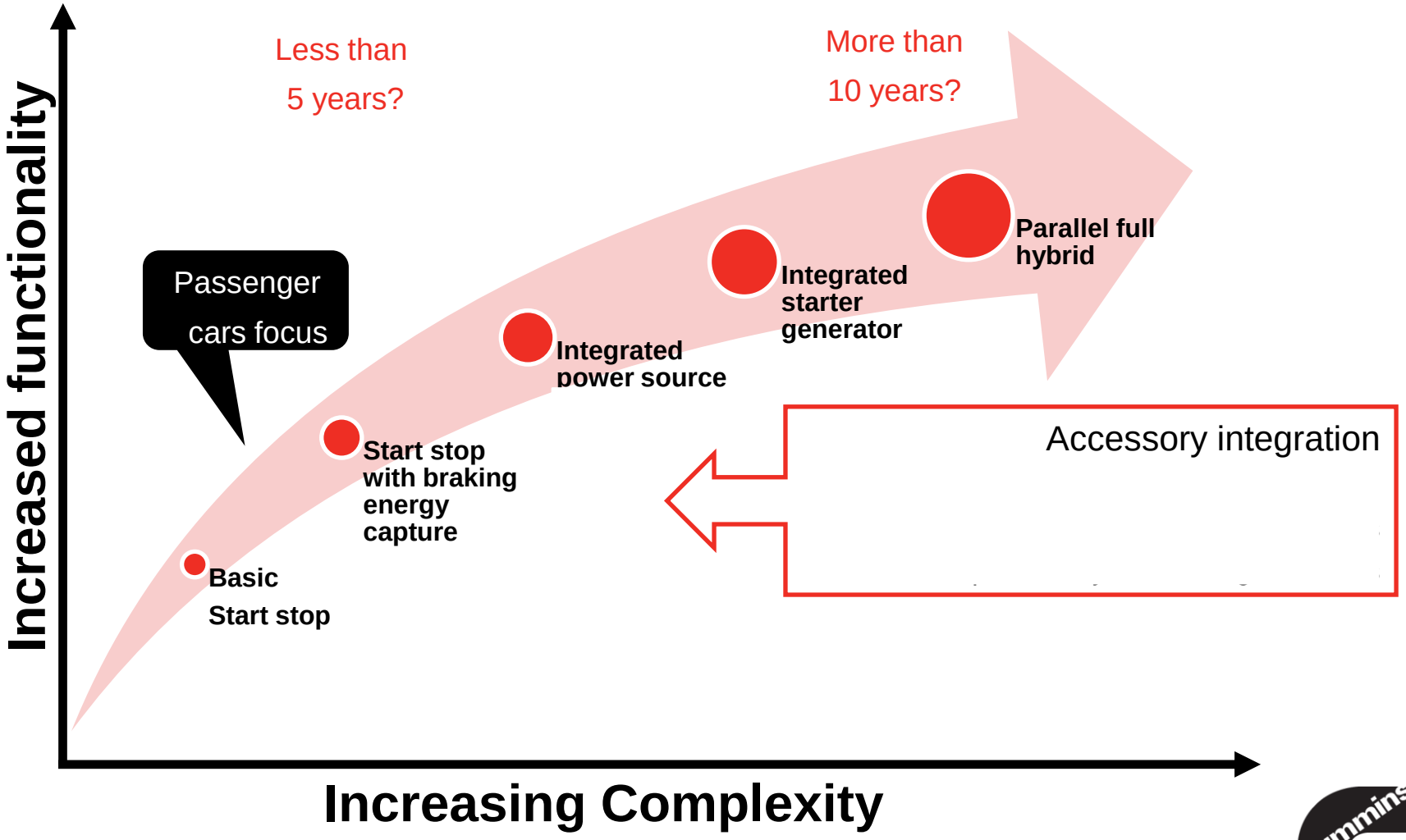
Feature	Description	Benefit	Inputs	Map	AMT
Predictive Cruise Control	Dynamically adjusts vehicle speed			•	o
Operator Cost Management	Optimizes total cost of operation			•	
Transient Torque Management	Manages available torque			o	o
Vehicle Deceleration Management	Provides shift recommendations			•	o
Vehicle Coasting Management	Manages transmission			o	o

• = Required by Feature o = Availability Further Enhances Feature Performance

Further Feature Optimisation



Alignment With A Long Term Vision Of Gradual Electrification



Cummins Confidential

India Roadmap….

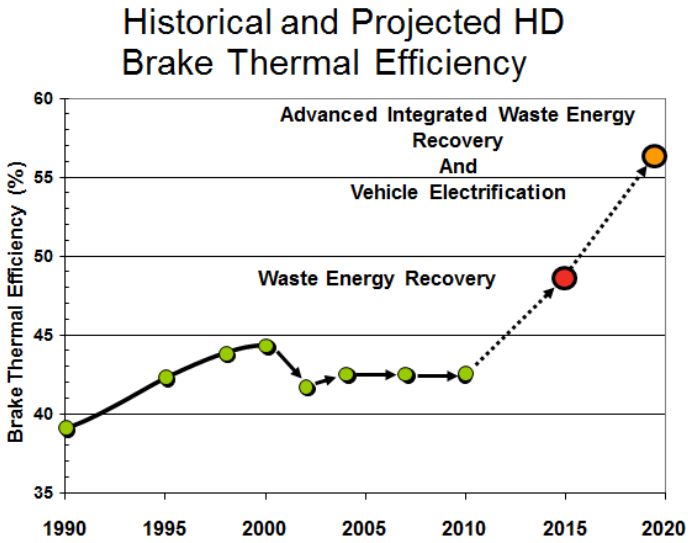
- Criteria emissions
  - Stable legislation and clear implementation timeline
  - One Country, One Fuel, One Norm
  - Full enforcement

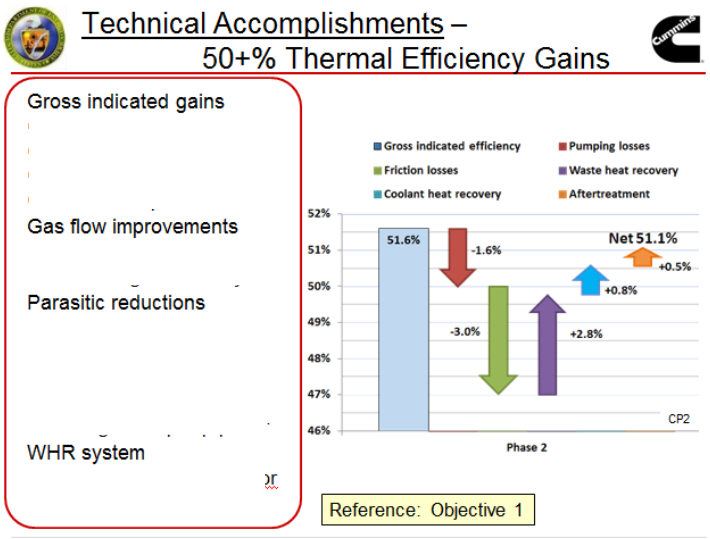
- More focus on Fuel consumption and CO_2 reduction
  - Separate engine and vehicle standards
  - Lead-time, clarity and certainty for efficiency improvements and technology development

“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