

# Next Generation Natural Gas Vehicle (NGNGV) Program Review

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# NGNGV Program

U.S. Department of Energy initiative starting in 2000

- Develop working prototypes to meet 2010 emission standards (0.5 g/bhp\*h NO<sub>x</sub> proposed, 0.2 g/bhp\*h final)
  - Class 3-6 vehicle applications
  - Class 7-8 vehicle applications
- Leverage funding & previous DOE advance development efforts
- Competitive with conventional fueled vehicles
  - Initial cost
  - Operating costs



# NGNGV Program

- Vehicle Working Group established in 2000
- Multiple workshops held with > 40 industry stakeholders:
  - Engine and vehicle OEMs
  - Industry and trade associations
  - Fleet operators
  - National labs
  - Utilities and fuel distributors
  - Equipment suppliers
  - Consultants and universities
- South Coast Air Quality Management District
- California Energy Commission



# NGNGV Program

- Engine Performance
  - 1) Reduce capital and operating cost
  - 2) Increase fuel economy
  - 3) Improve maintainability
- Combustion Technology Development Areas
  - 1) DING
  - 2) Lean-SING
  - 3) Stoichiometric-SING
- Emission Control Areas
  - 1) Lean-NOx technology
  - 2) THC reduction
  - 3) Oxidation catalyst
- Perform market research for NG target applications
- Near-term development encouraged (2004/2002.5)
- VWG results and recommendations available on <http://www.nrel.gov/vehiclesandfuels/ngvtf/pdfs/37647.pdf>

# NGNGV Integrated R&D Strategy



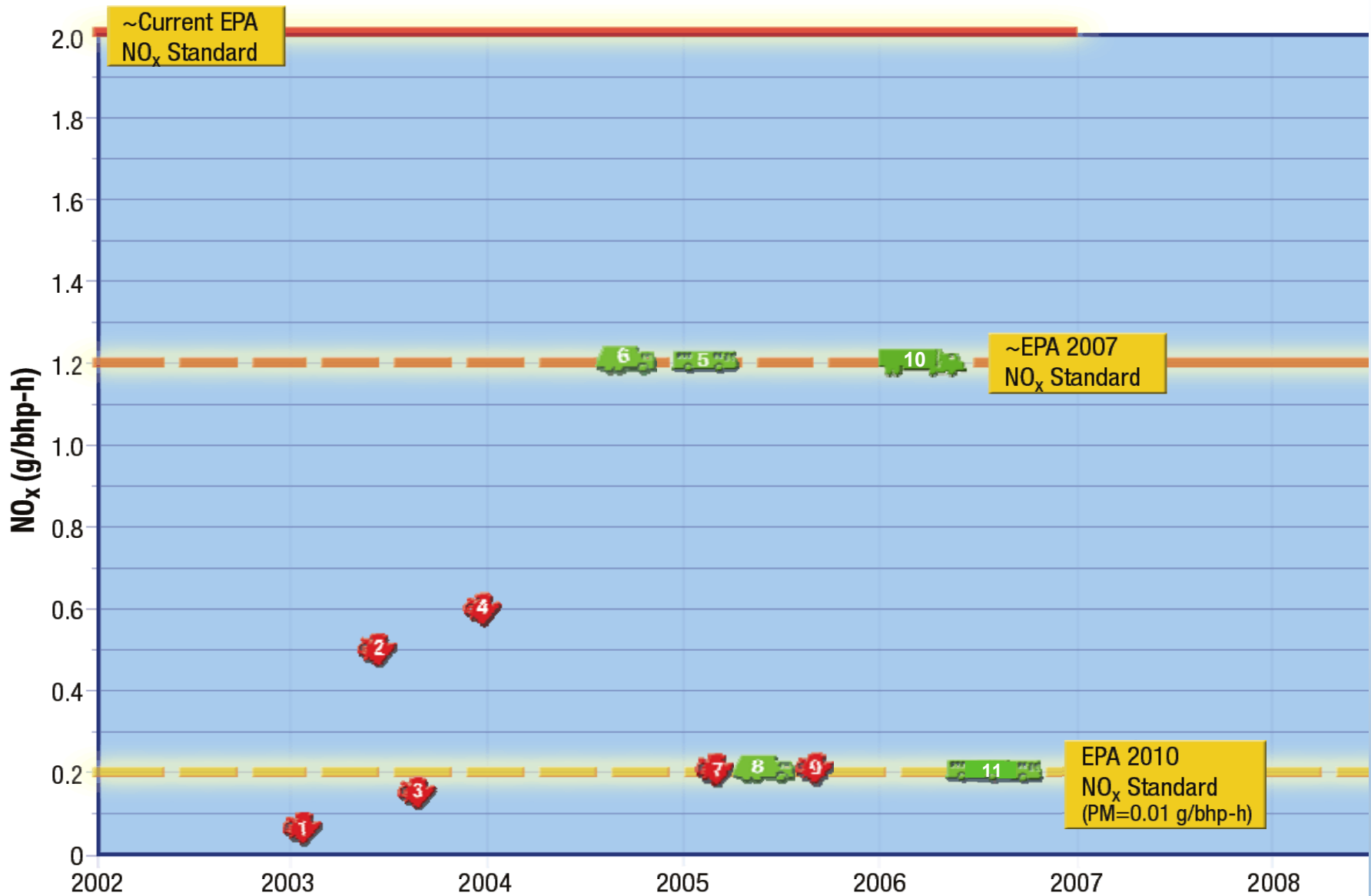
Research Development

Engine/Vehicle Development

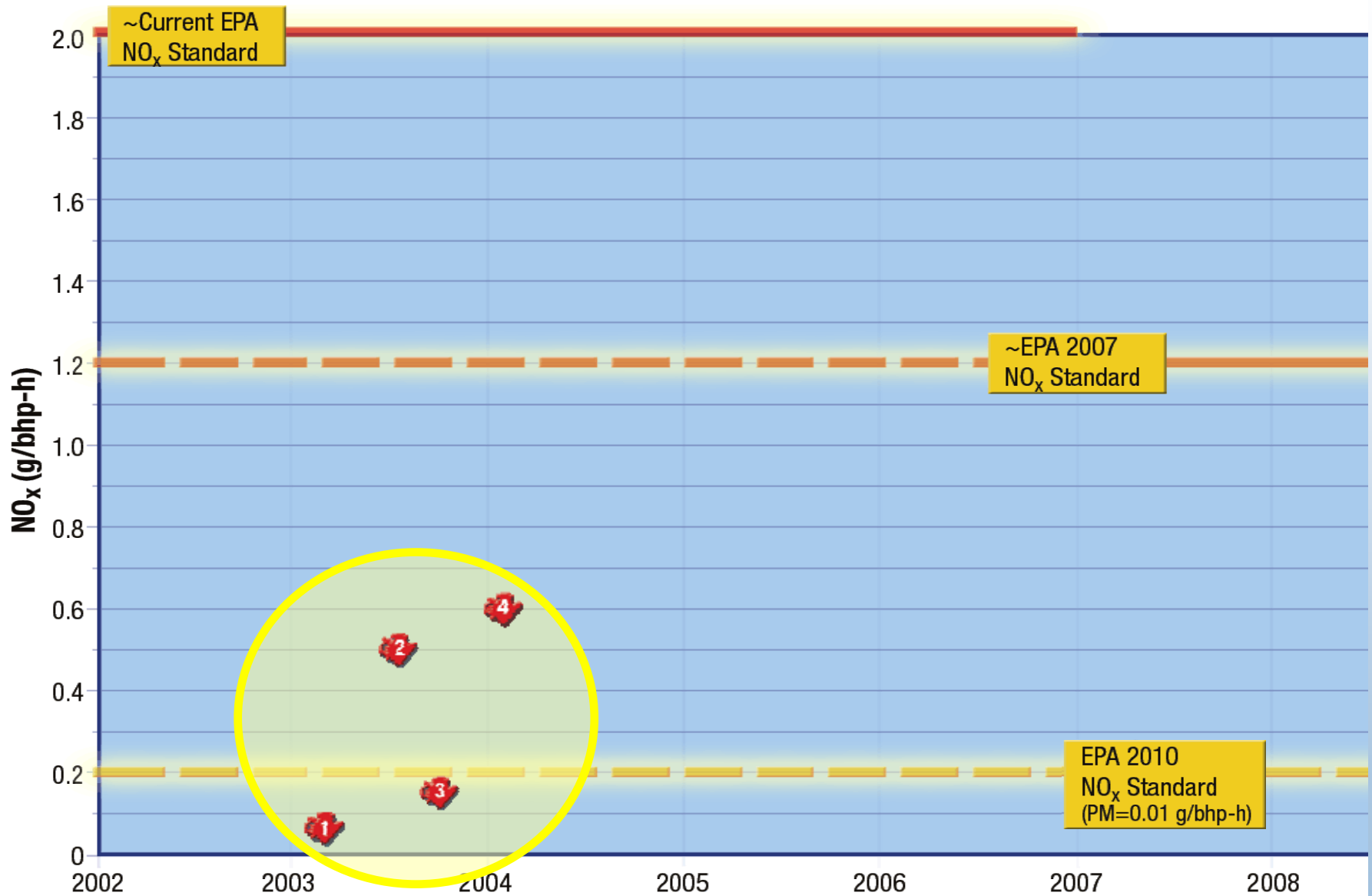
Engine Laboratory Development

Proof of Concept

# NGNGV Projects



# Proof of Concept Projects



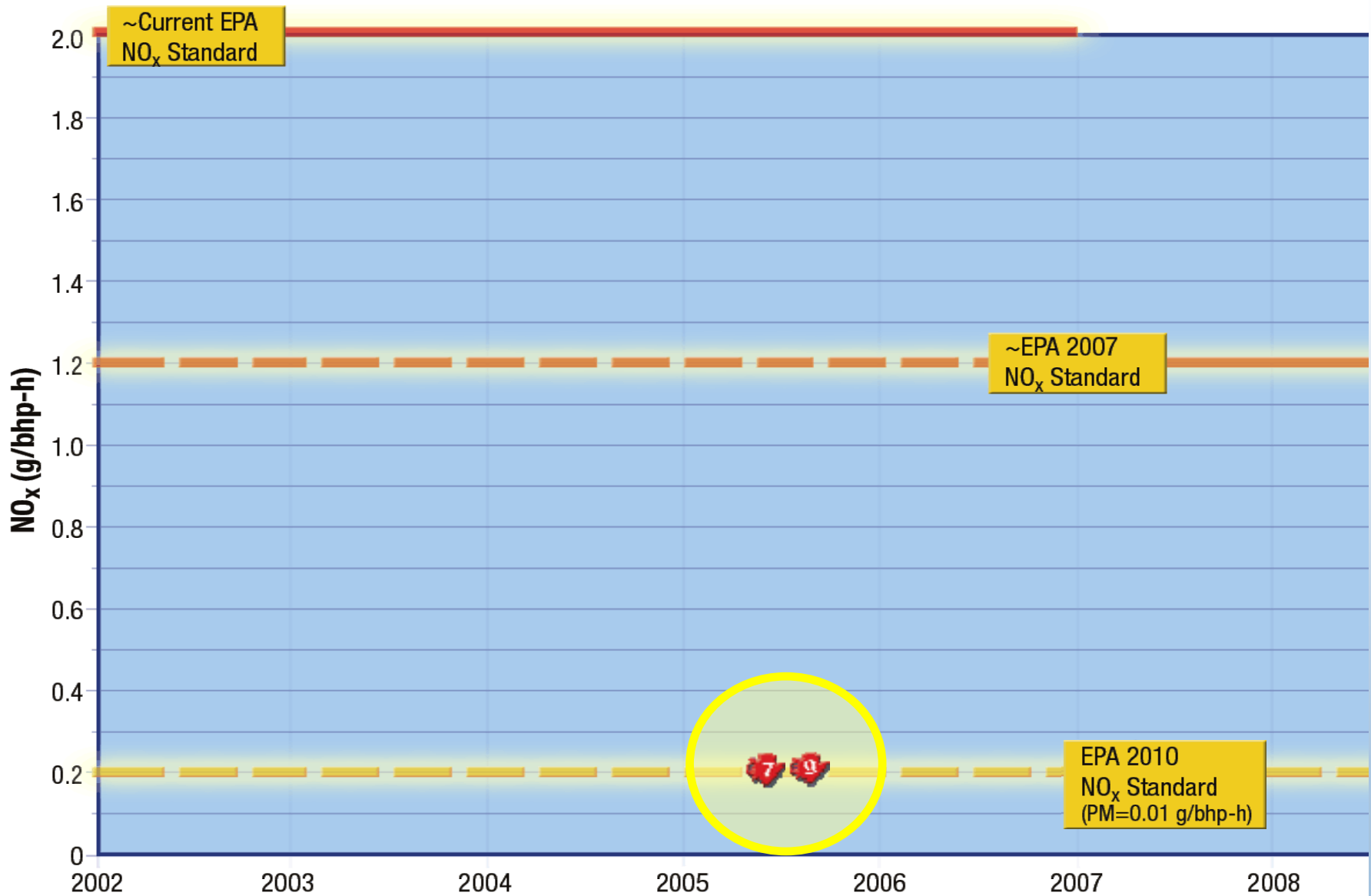
# Proof of Concept Projects

## Findings and Results:

- (Better than) 2007 emission standards demonstrated with Class 8 capable engines
  - 1) Clean Air Power C12 Dual-Fuel-- 0.5 g/bhp\*h NO<sub>x</sub>
    - Prototype EGR & commercially available DPF
    - ESC 13
  - 2) Cummins Westport High Pressure Direct Injection ISX-- 0.6 g/bhp\*h NO<sub>x</sub>
    - Increased EGR & oxidation catalyst
    - FTP
- 2010 emission levels demonstrated
  - 1) Teleflex/GFI-- 0.08 g/bhp\*h NO<sub>x</sub>
    - Production 6.0L NG engine w/optimized 3-way catalyst
    - FTP
  - 2) Cummins Westport B Gas Plus-- 0.15 g/bhp\*h NO<sub>x</sub>
    - Spark-ignited lean-burn @ 1.2 g/bhp\*h NO<sub>x</sub>
    - CWI's "NO<sub>x</sub> Storage and Reduction" (NSR) system
    - AVL 8



# Engine Laboratory Projects





## Cummins Laboratory Development stoich-SING, EGR, TWC w/ 8.3L

### Project Targets:

- Stoichiometric air/fuel (& EGR) control
- 2010 emission demo (AVL8/FTP)
- Engine ratings 310 hp/950 ft-lb
- 40% peak thermal efficiency

### Status:

- Steady-State laboratory engine operation has demonstrated
  - 2010 emission viability
  - Peak efficiency target
  - Engine rating targets
- Transient calibration development initiated

Contact: Naveen Berry (SCAQMD)





# Mack Laboratory Development stoich-SING, EGR, TWC, VVT w/11 L

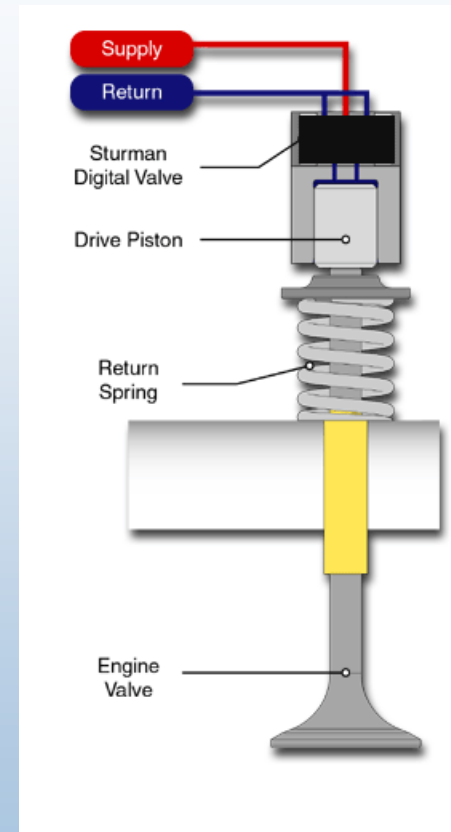
## Project Targets:

- Multimode steady-state operation
- Stoichiometric air/fuel (&EGR) control
- 2010 emission demonstration (Mack 16)
- Variable valve operation
- Engine ratings 325 hp/1,250 ft-lb

## Status:

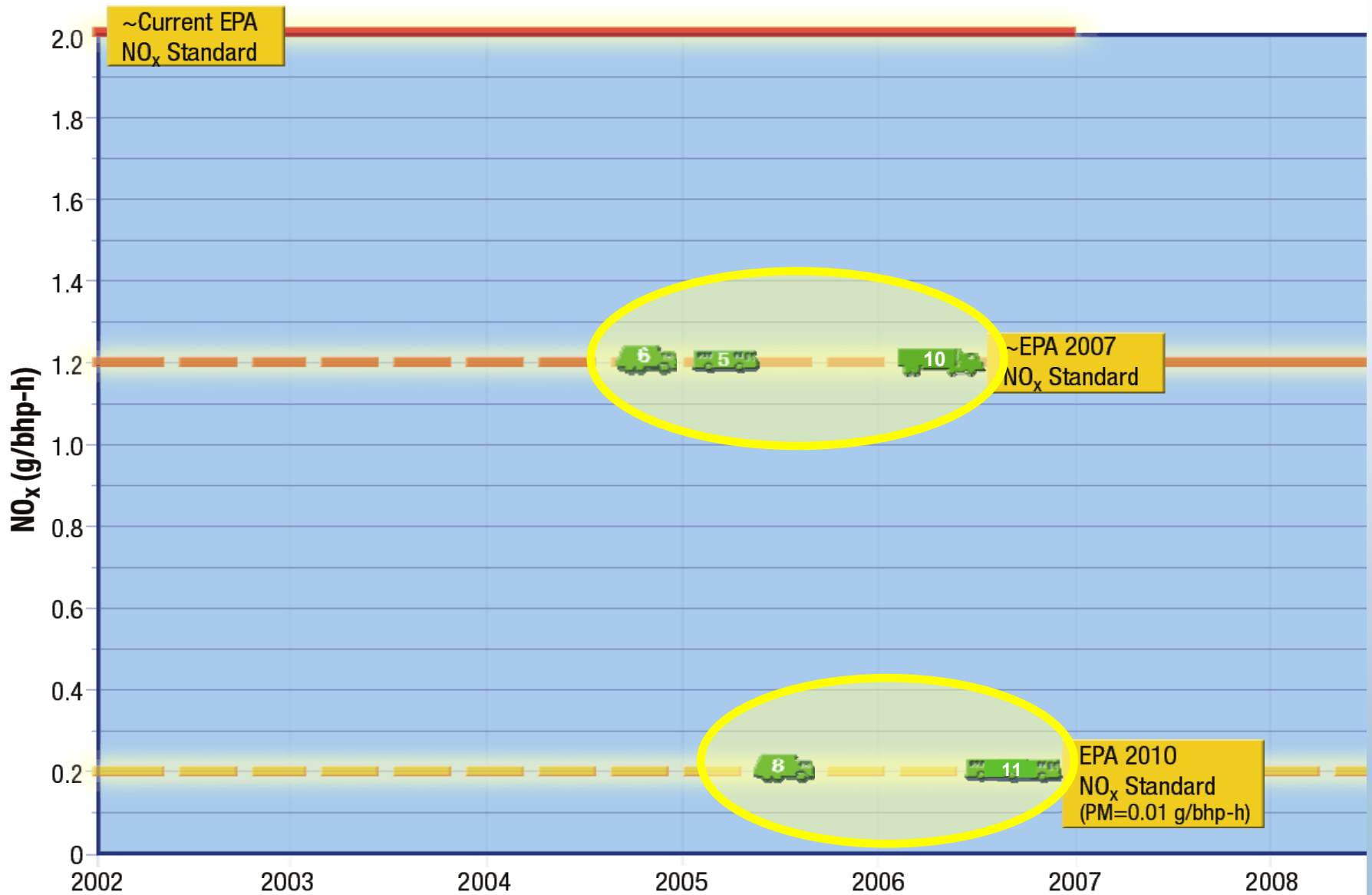
- Engine assembled
- VVT Head assembled

Contact: Margo Melendez (NREL)



Sturman DHOS™ Valve  
Actuation Module

# Engine/Vehicle Development





# Deere Power Systems 6081 Engine/Vehicle Development

## Results:

- DPS proprietary engine controls
- Engine ratings 280 hp/900 ft-lb
- 6 months operational fleet data

Contact: Richard Parish (NREL)



## **Significance:**

Introduction of DPS 6081 to transit bus market and increased NG engine availability

- Deere certified the engine to 1.5 g/bhp NO<sub>x</sub> + NMHC



## Cummins Westport L Gas Plus Engine/Vehicle Development

### Results:

- Implemented Plus Technology to larger 8.9L
- Engine ratings 320 hp/1,000 ft-lb
- Development data four fleets w/refuse & transit

Contact: Mike Frailey





## Cummins Westport L Gas Plus Engine/Vehicle Development

### Results:

- Implemented Plus Technology to larger 8.9L
- Engine ratings 320 hp/1,000 ft-lb
- Development data four fleets w/refuse & transit

Contact: Mike Frailey



### **Significance:**

Increased natural gas engine availability w/higher ratings

- CWI certified to 1.5 g/bhp NO<sub>x</sub> + NMHC
- OEM equipment availability w/ NABI & Autocar



## Westport Innovations HPDI ISX-G w/OC Engine/Vehicle Development

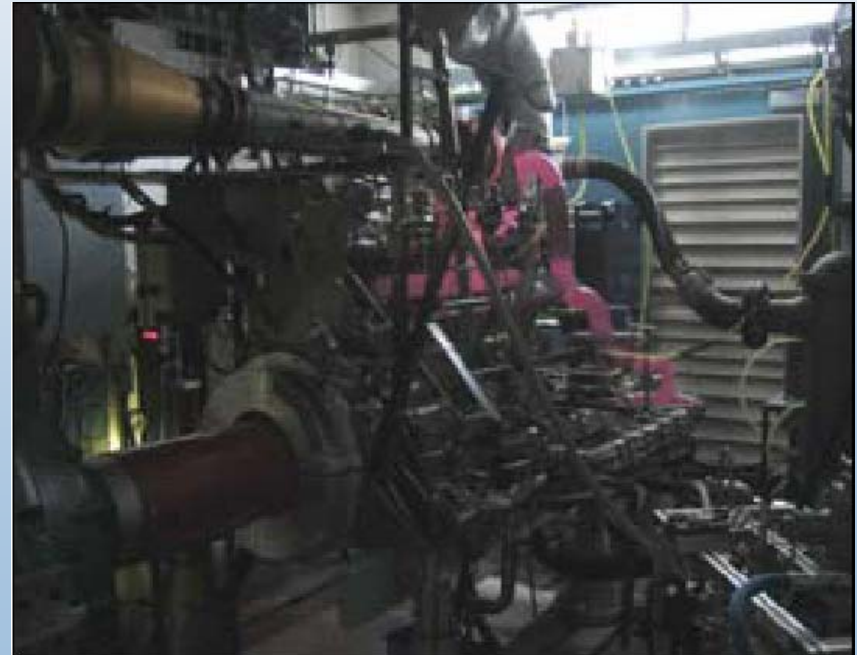
### Targets:

- Class 8 ratings, 450 hp/1,650 ft-lb
- Lean-burn combustion w/passive ECD
- 2007 emission standards (FTP)
- Assemble/operate prototypes vehicles

### Status:

- Project initiated Nov-04
- Engine calibration on-going
- Durability testing initiated

Contact: Richard Parish (NREL)







# Mack 12 L stoic-SING, EGR & TWC Engine/Vehicle Development

## Targets:

- Stoichiometric air/fuel (& EGR) control
- 2010 emission demonstration (FTP)
- 350 hp/1,250 ft-lb
- Assemble/operate 2 prototype vehicles

## Status:

- SS data demonstrated 2010 emissions
- Transient calibration progressing
- Parts procurement initiated, Apr/Mar build

Contact: Margo Melendez (NREL), Matt Miyasato (SCAQMD)





# CWI stoich-SING, EGR w/TWC 8.9L Engine/Vehicle Development

## Targets:

- Stoichiometric air/fuel (& EGR) control
- 2010 emission demonstration (FTP)
- 320 hp/1,000 ft-lb
- 40% peak thermal efficiency
- Assemble/operate prototypes



## Status:

- Project initiated Feb-06
- Leverage experience from SCAQMD funded technology development project

Contact: Mike Frailey (NREL)

# NGNGV Progress on VWG Objectives

- Engine Performance
  - Reduce costs- ✓ operating cost parity; lean-SI v. D2 (NREL evaluation data)
  - Improve fuel economy- ✓ improved 16-18% lower than current D2 (NREL eval. data)
  - Improve maintainability- ✓ product maturity, diagnostic tools available (NREL eval.)
- Combustion Technology Development
  - DING: ✓ prototype development vehicles @ 1.2 NOx planned
  - Lean-SING: ✓ new products @ 1.2 NOx available
  - Stoich-SING: ✓ prototype development vehicles @ 0.2 NOx planned
- Emission Control Development
  - Lean-NOx: ✓ CWI “NSR” tested- catalyst degradation, controls, packaging
  - THC reduction: ✓ oxidizing & 3-way catalysts reduce HC, ✗ CH4 reduction difficult
  - Oxidation catalyst: ✓ optimized/certified for ‘07 lean-SI, planned for ‘07 DI develop
- Market research for vehicle applications: ✓ for now- transit & refuse
- Near-term development (2004/2002.5): ✓ DPS 6081, CWI L Gas Plus

# NGNGV Progress on DOE Objectives

- Develop and operate prototype vehicles that can meet 2010 emissions
  - ✓ 2 Prototype engines will be fleet tested at 2010 emission levels-
    - Mack stoich-SI/EGR/TWC- refuse collection fleet, spring/summer '05
    - CWI stoich-SI/EGR/TWC- refuse and/or transit fleets, early '06
  - ✓ 1 Prototype engine will be fleet tested at 2007 emission levels
    - Westport HPDI ISX- Class 8 tractor applications, late '05
- Leverage funding & previous DOE advance development efforts
  - ✓ Funding & human resources roughly doubled by SCAQMD and CEC
  - ✓ Lean-SI & DI work evolved directly from previous development efforts

# NGNGV Progress on DOE Objectives

- Economically competitive with conventional fueled vehicles

## Competition is good but changing

- Diesel fueled vehicles are going to change to meet 2007 and 2010
- Diesel and gasoline heavy-duty hybrids are new and evolving
- What is going to happen with the competition as they too have to comply with 2010 emission regulations?

## NG engine products continue to evolve

- EGR has enabled significant NO<sub>x</sub> reduction in DING engine systems
  - ✓ ~80% reduction of NO<sub>x</sub> in laboratory demonstrations
- EGR has enabled TWC systems to be incorporated with SING products
  - ✓ 2010 emissions demonstrated
  - ✓ Cost is expected to be slightly higher than current lean-SI
  - ✓ Stoichiometric-SING/EGR/TWC could be the competition in 2010!

## Acknowledgements:

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NGNGV Objectives/ Working Group Document

[www.nrel.gov/vehiclesandfuels/ngvtf/pdfs/37647.pdf](http://www.nrel.gov/vehiclesandfuels/ngvtf/pdfs/37647.pdf)