U. S. Mobile Source Non-road Black Carbon Emissions

Workshop on Emissions of Black Carbon and Their Implications for Climate Change
October 13-15, 2004

Engine Manufacturers Association

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Acknowledgements

- Engine Manufacturers Association
  - Engine Emissions
- U. S. Environmental Protection Agency
  - PM2.5 Inventory
- University of Minnesota
  - Diesel Particle Size Distributions

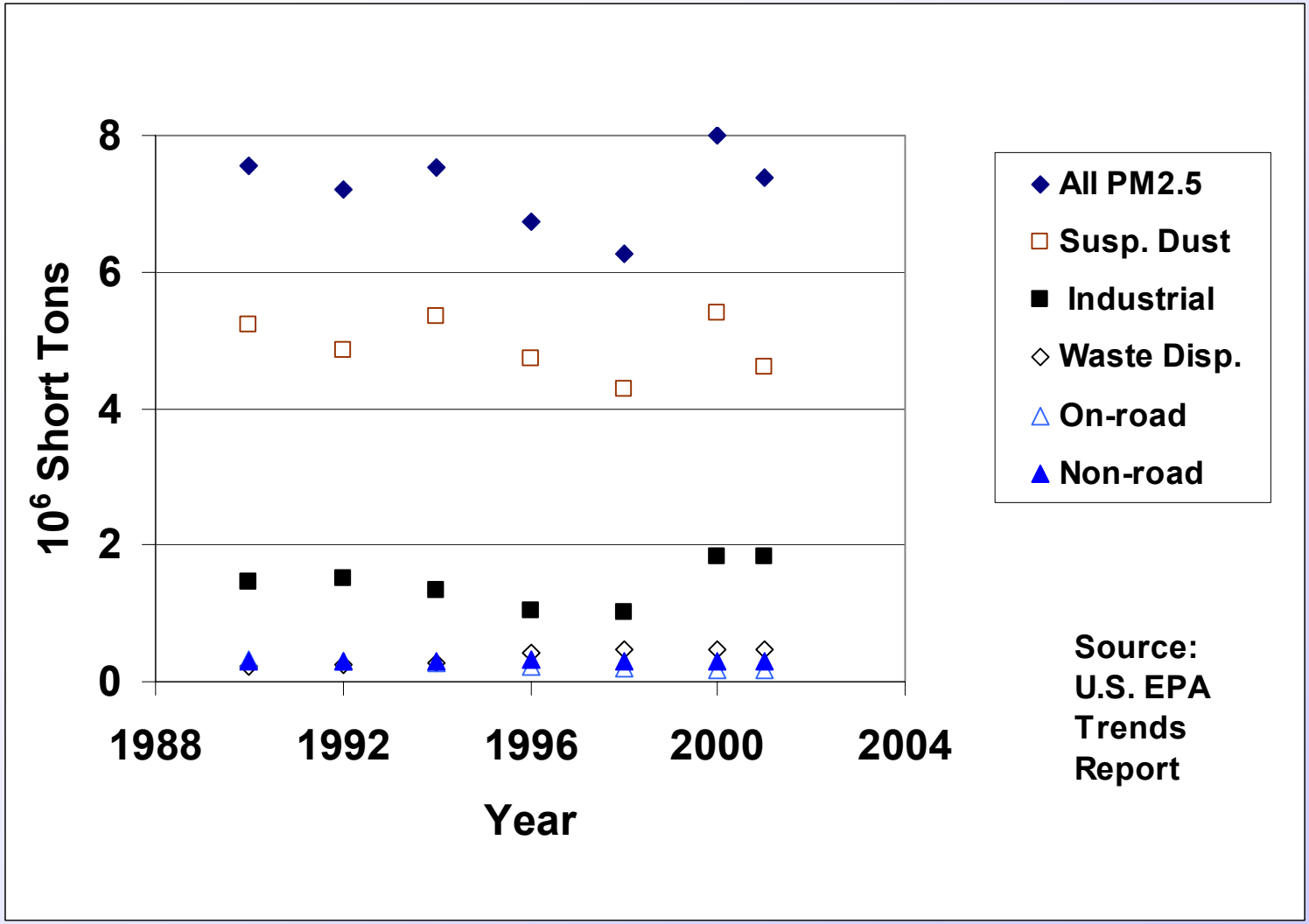
Outline

- PM2.5 Source Categories
- PM Trends
- Non-road Contributions
- Regulation Impact
- Emissions Examples

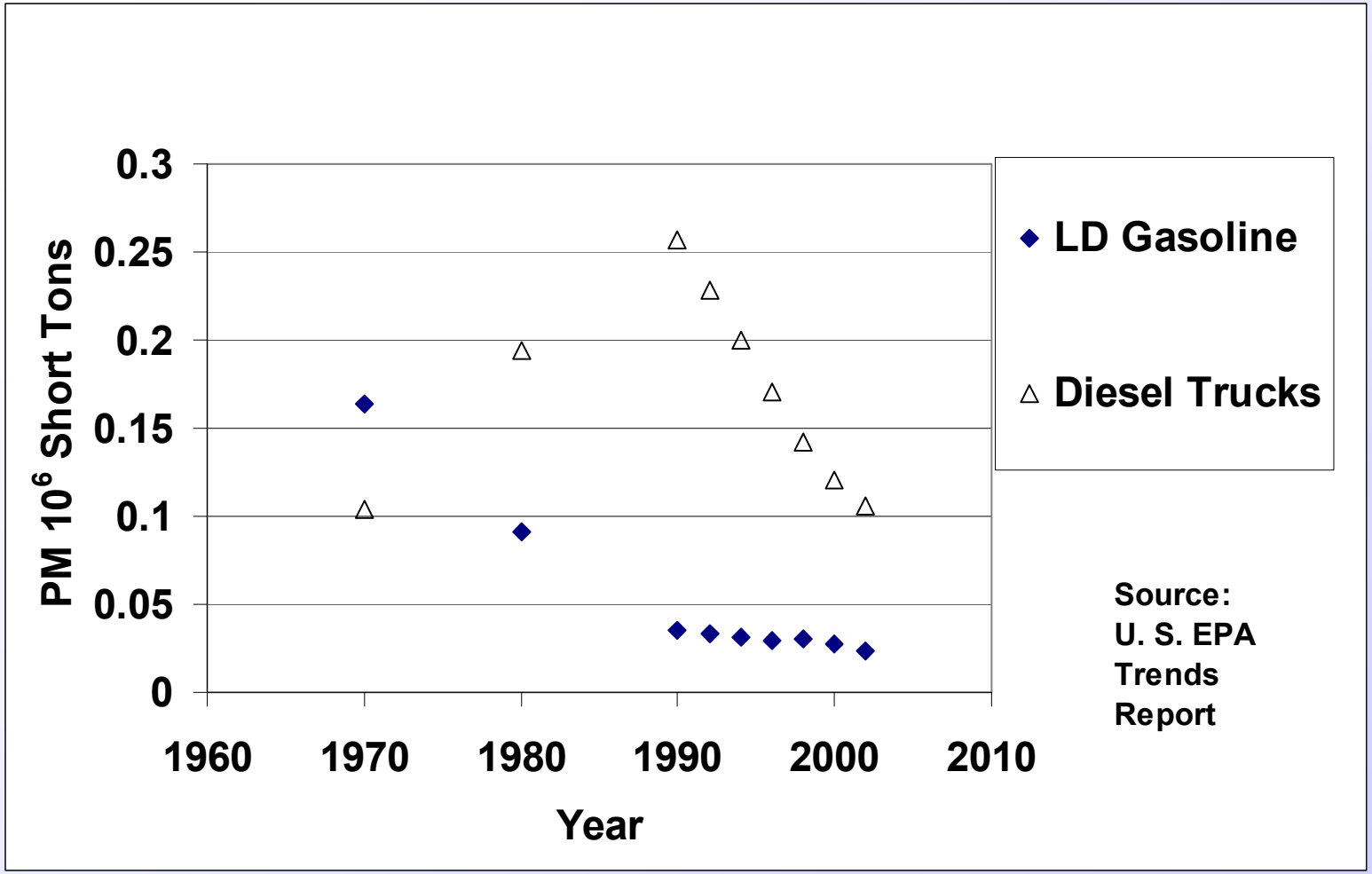
PM2.5 Source Categories

- Suspended Dust
- Industrial
- Waste Disposal
- On-road
- Non-road

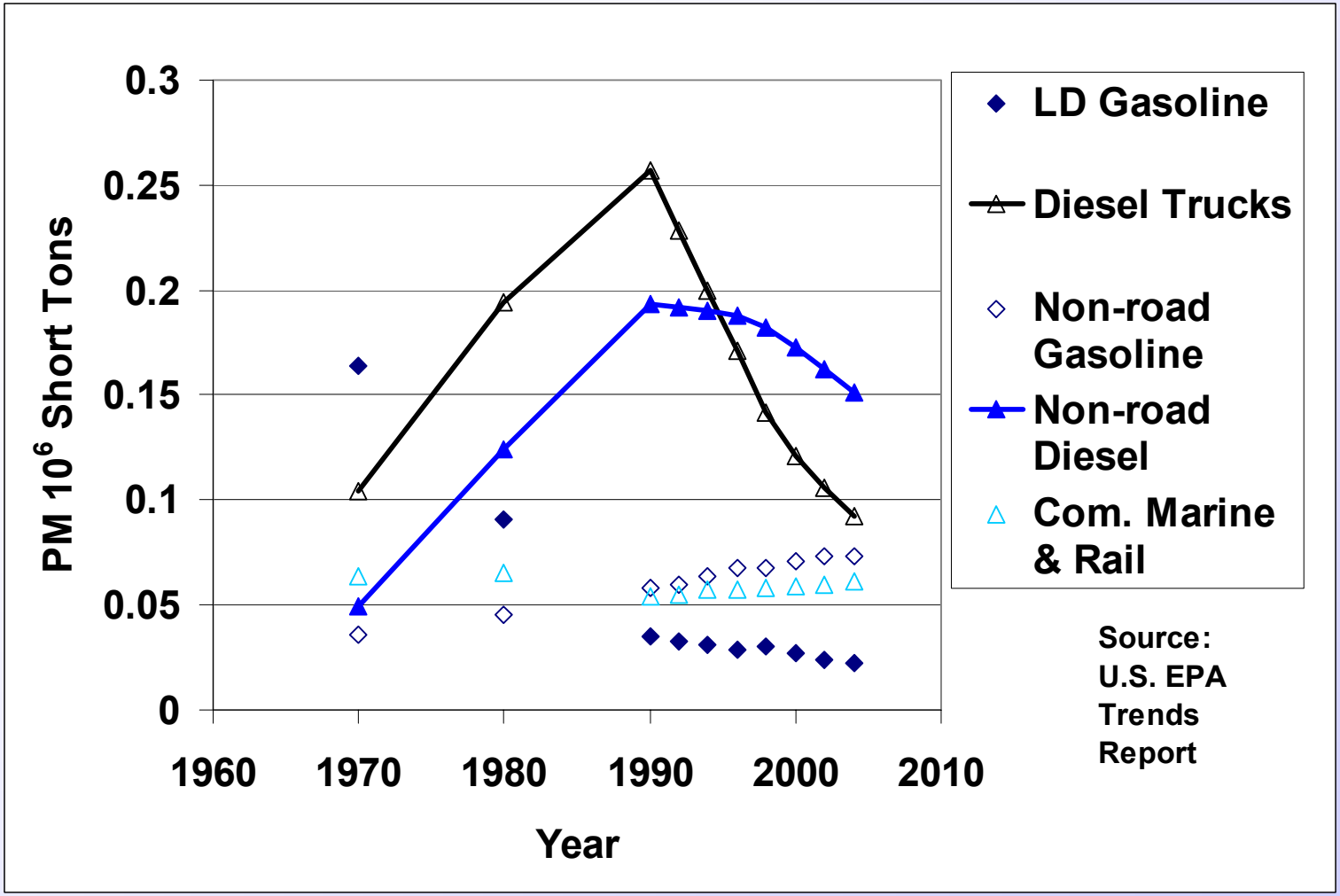
U. S. PM 2.5 Trends



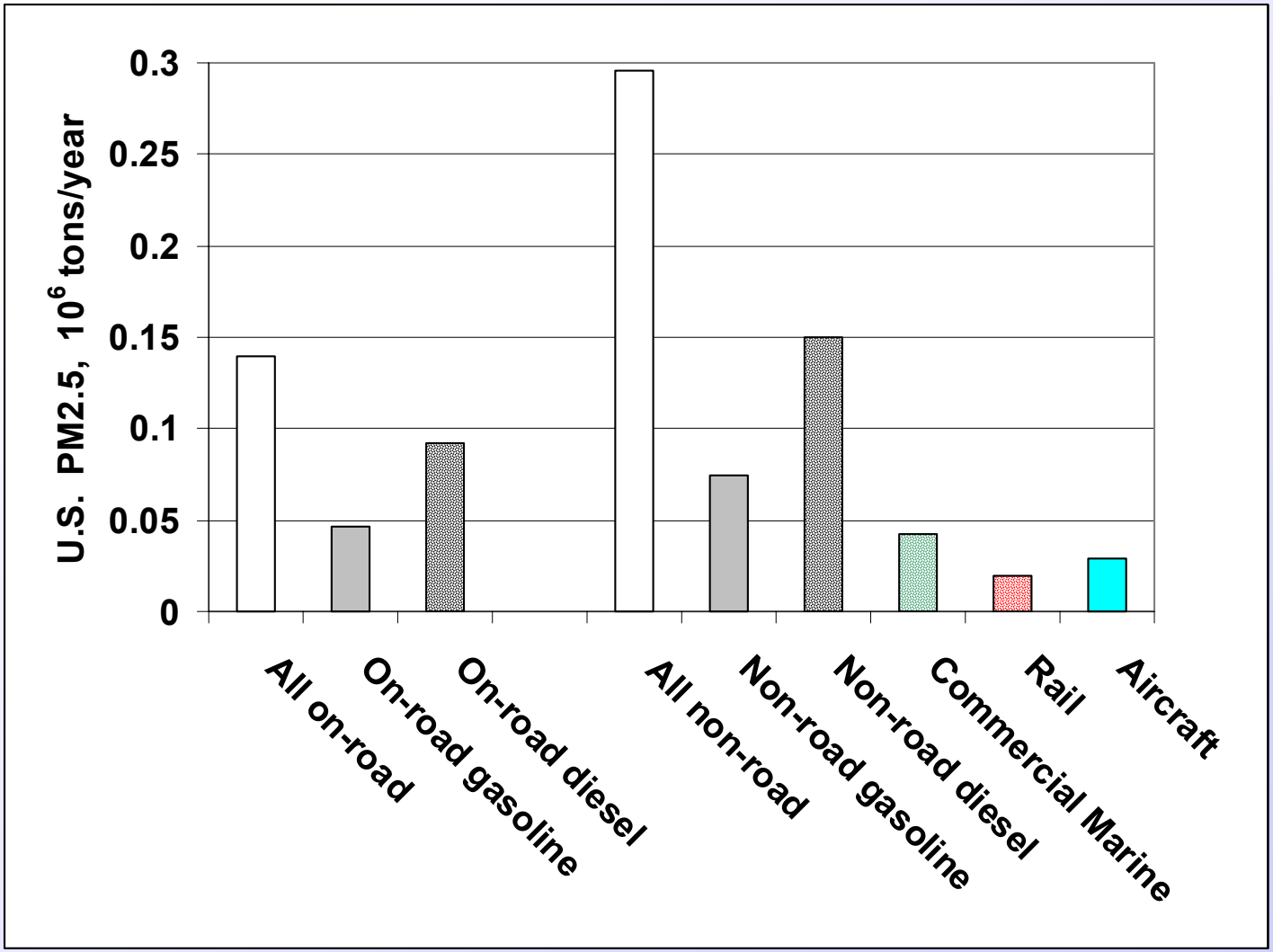
Largest On-road PM2.5 Categories



PM2.5 On-road and Non-road Comparison



2004 U.S. On-road and Non-road PM2.5



Non-road Equipment

- Recreational
- Construction
- Industrial
- Lawn & Garden
- Farm
- Logging
- Air
- Rail
- Marine
- Light commercial
- Airport service
- Railway maintenance

Non Road Equipment Examples

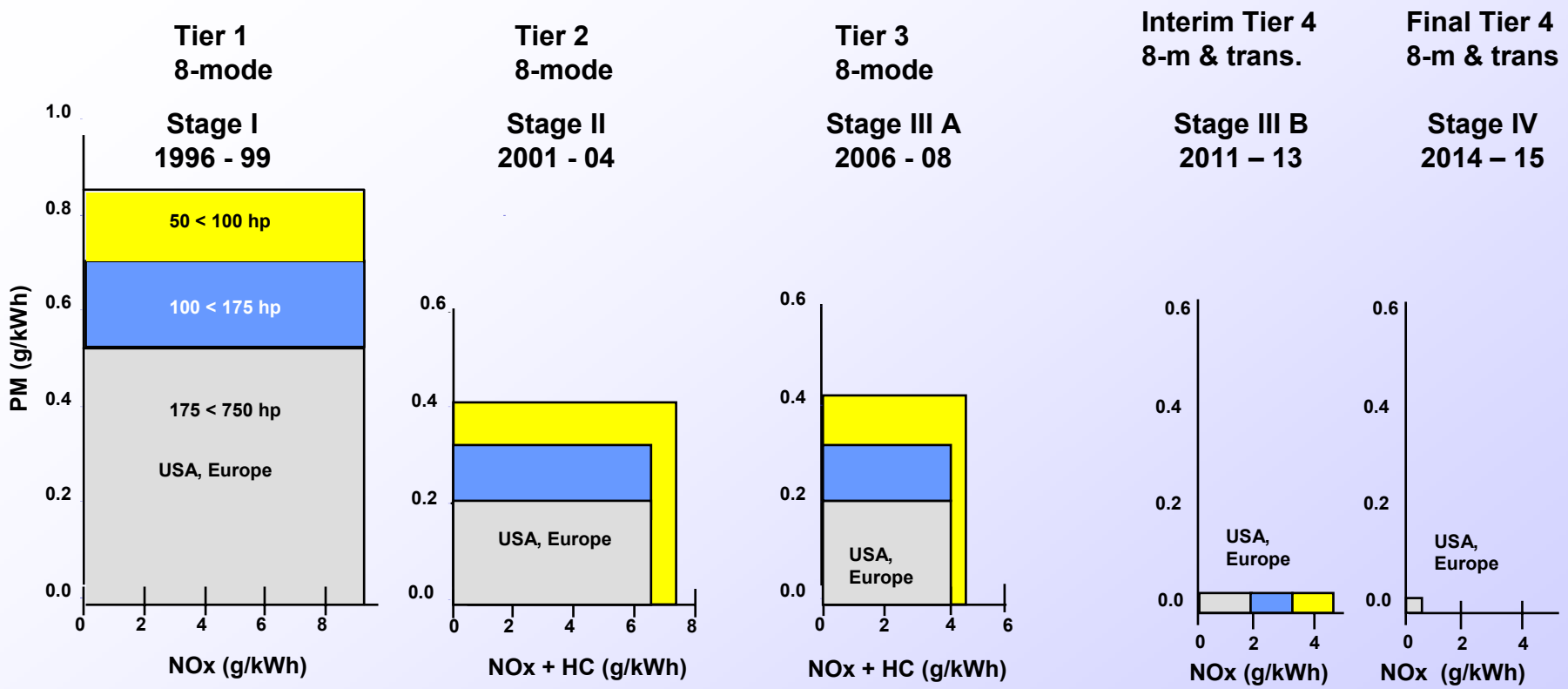
Tractor in Rice Field

Non-road Diesel Regulations

Authorized by 1990 CAA Amendments

- Effective mid-1990's
- Standards
  - Related to engine size
  - Phased in over multi-years
- Evaluation tests
  - Tiers 1 - 3 are steady-state
  - Tier 4 - transient and steady-state

Non-road Emission Regulations: 50 - 750 HP



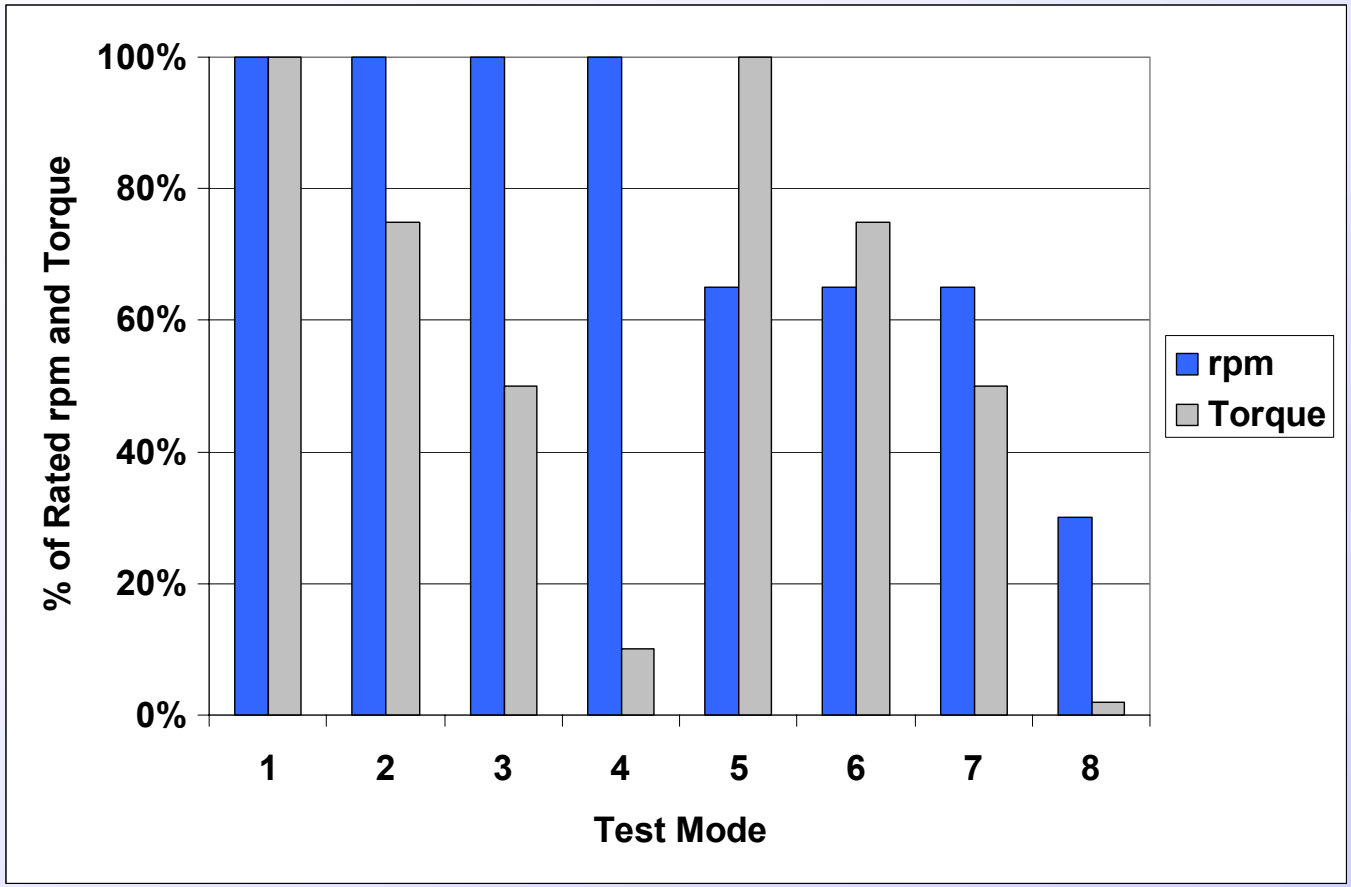
NONROAD (US) 3500 ppm sulfur → 500 ppm | 15 ppm

NONROAD (EU) 10 – 2000 ppm → 10-1000 ppm | 10 ppm ?

ONROAD (US) 500 ppm → 15 ppm

ONROAD (EU) 10 – 350 ppm → 50 ppm | 10 ppm

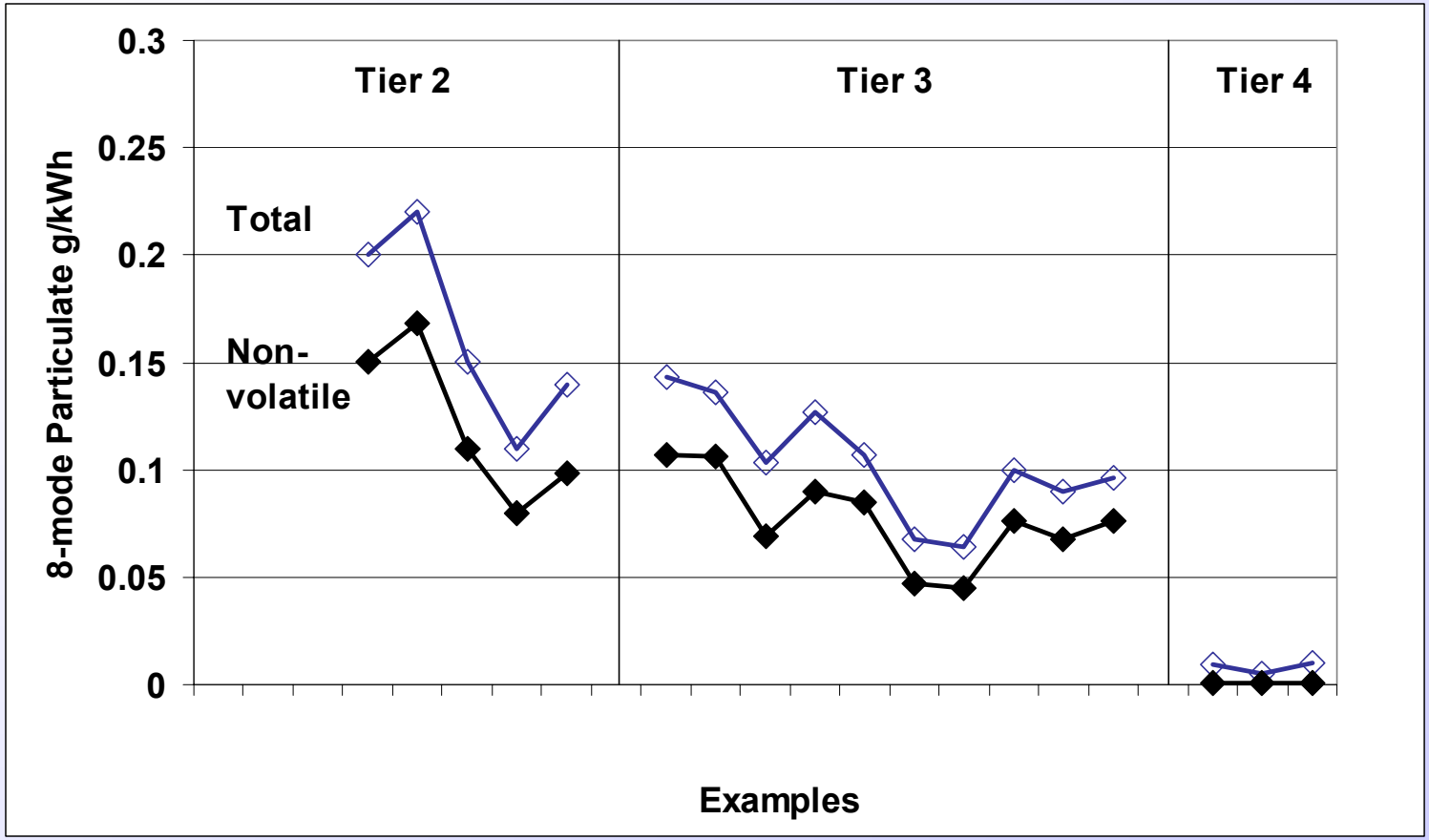
8-mode Test


100%
80%
60%
40%
20%
0%
% of Rated rpm and Torque
1
2
3
4
5
6
7
8
Test Mode
rpm
Torque

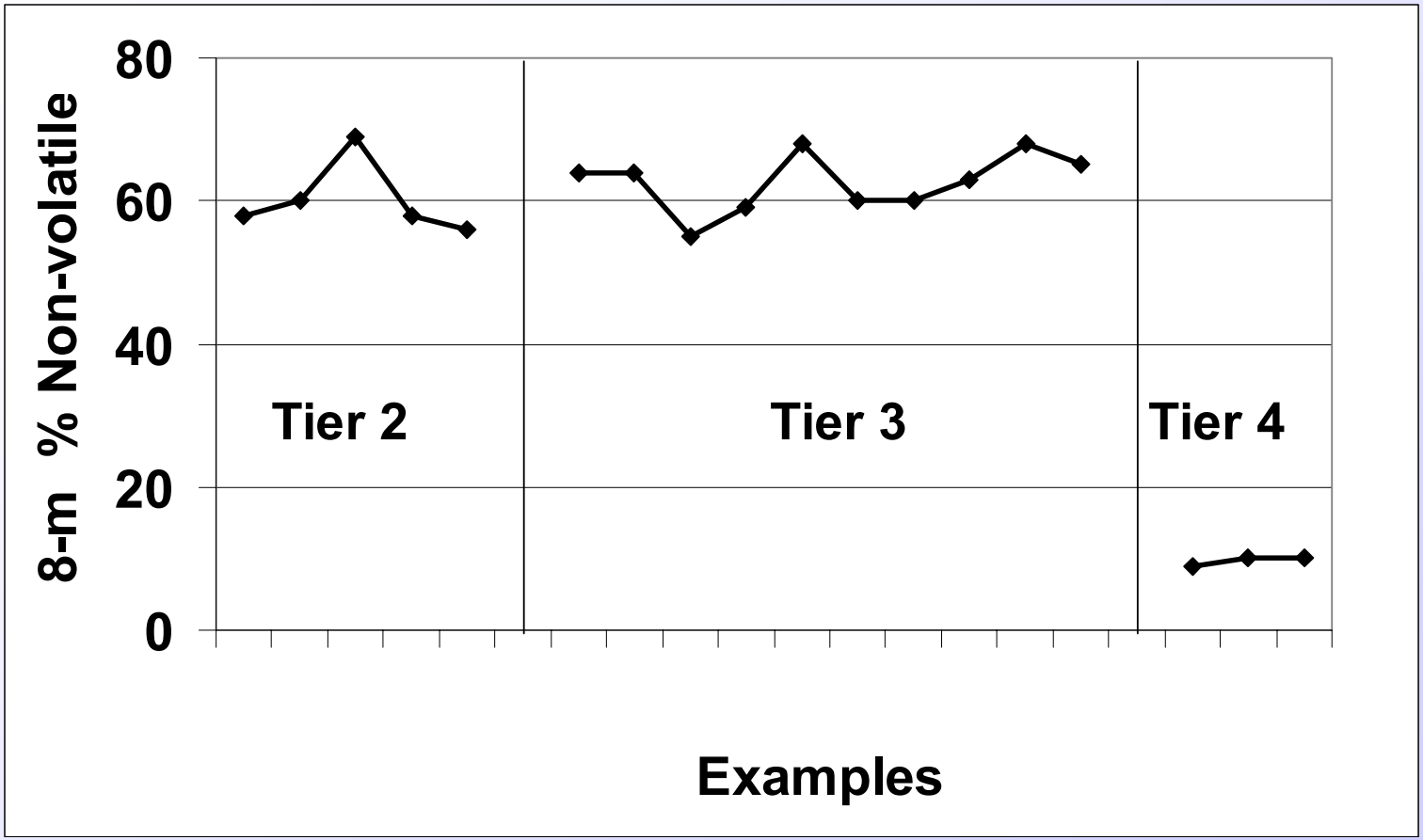
Non-volatile PM

- Separate volatile from non-volatile PM
- Heat filters in vacuum oven (<10 mm Hg)
- New filters Heated at 200C for 3 hours
- Heat filters with PM at 200C for 2 hours
- In 4 hours, 10% more volatile removed
- Data reported - likely high by 10%
- Non-volatile is similar to black carbon

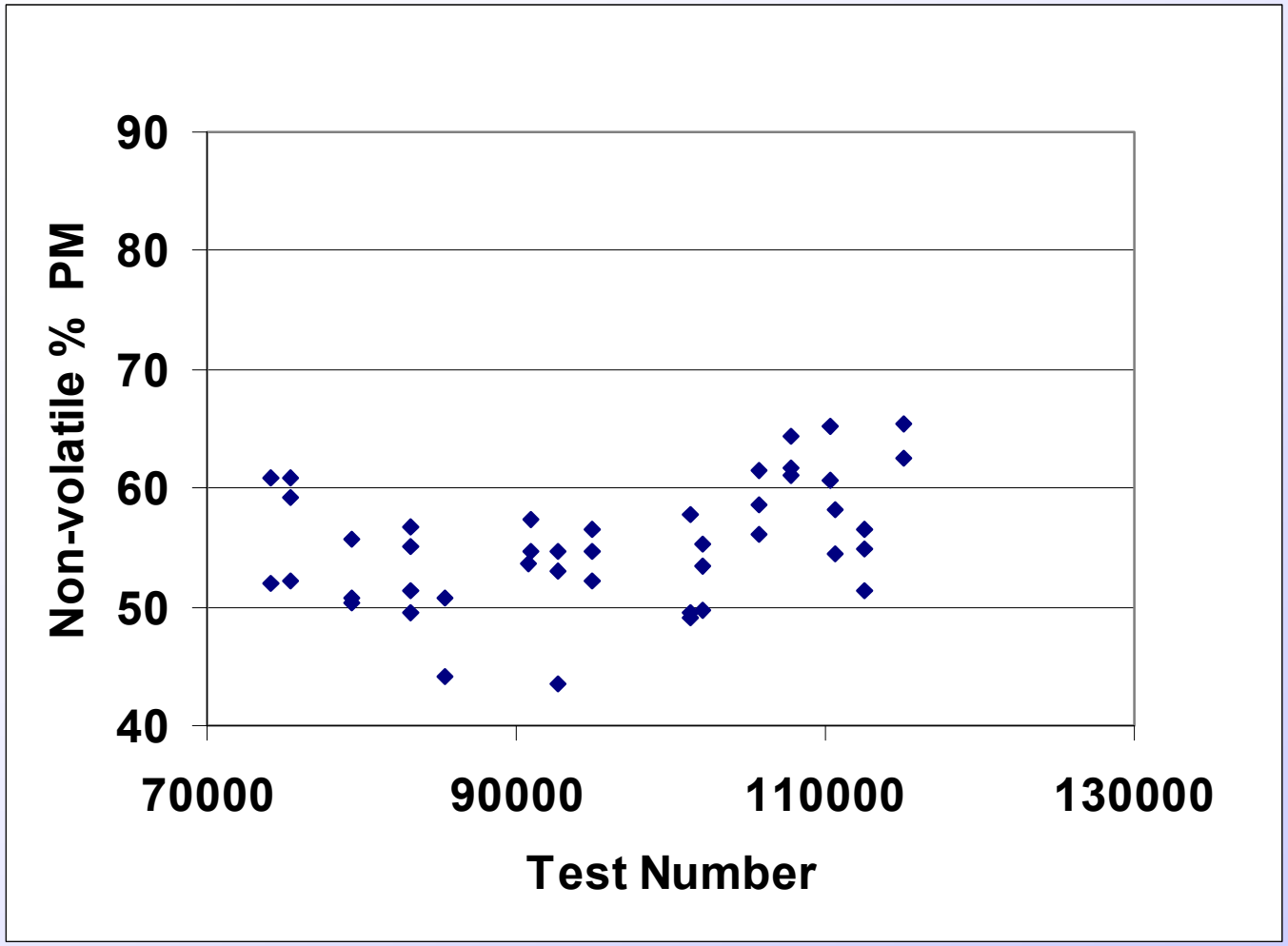
Non-volatile and Total PM for Tier 2 – Tier 4 Engines



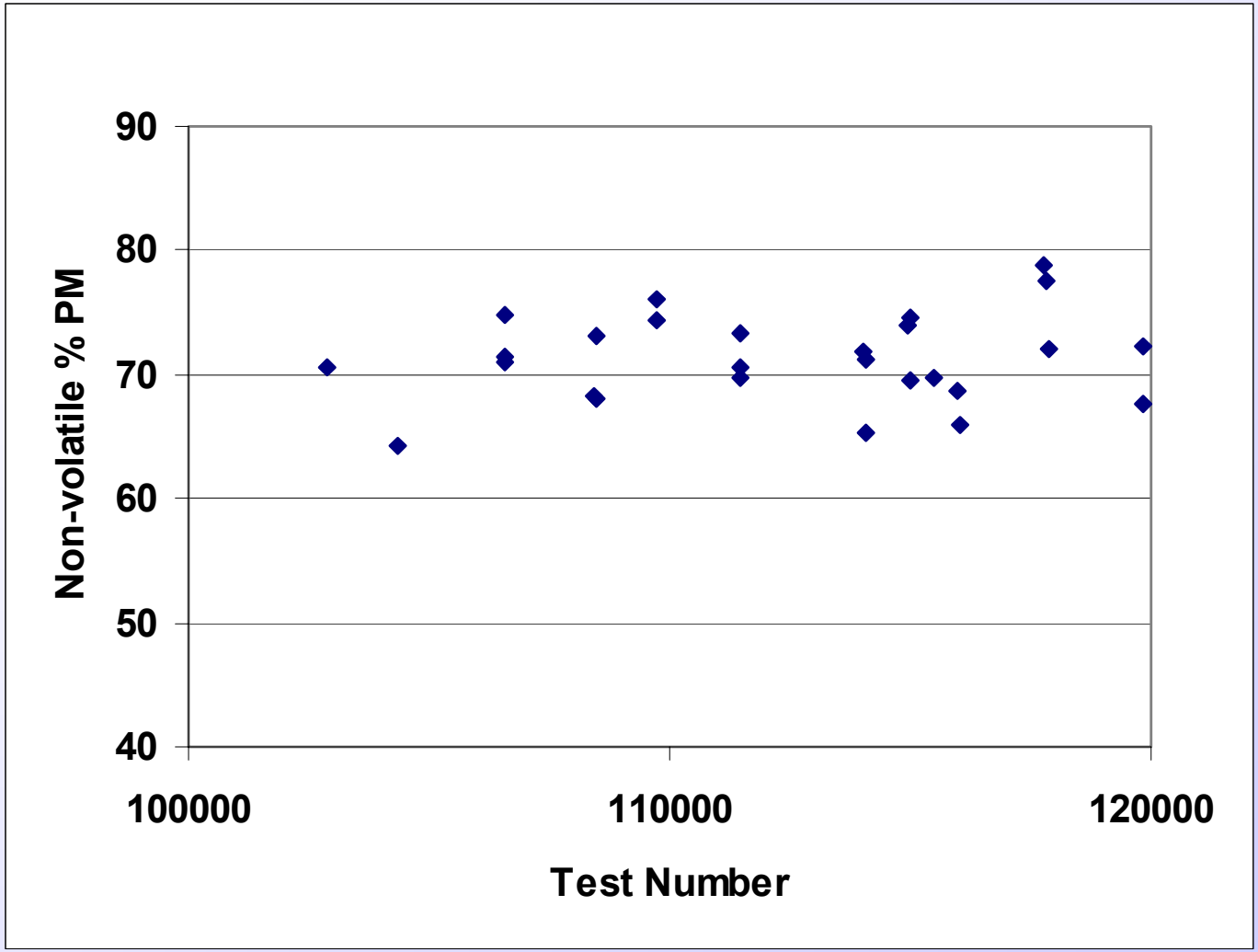
8-mode % Non-volatile PM



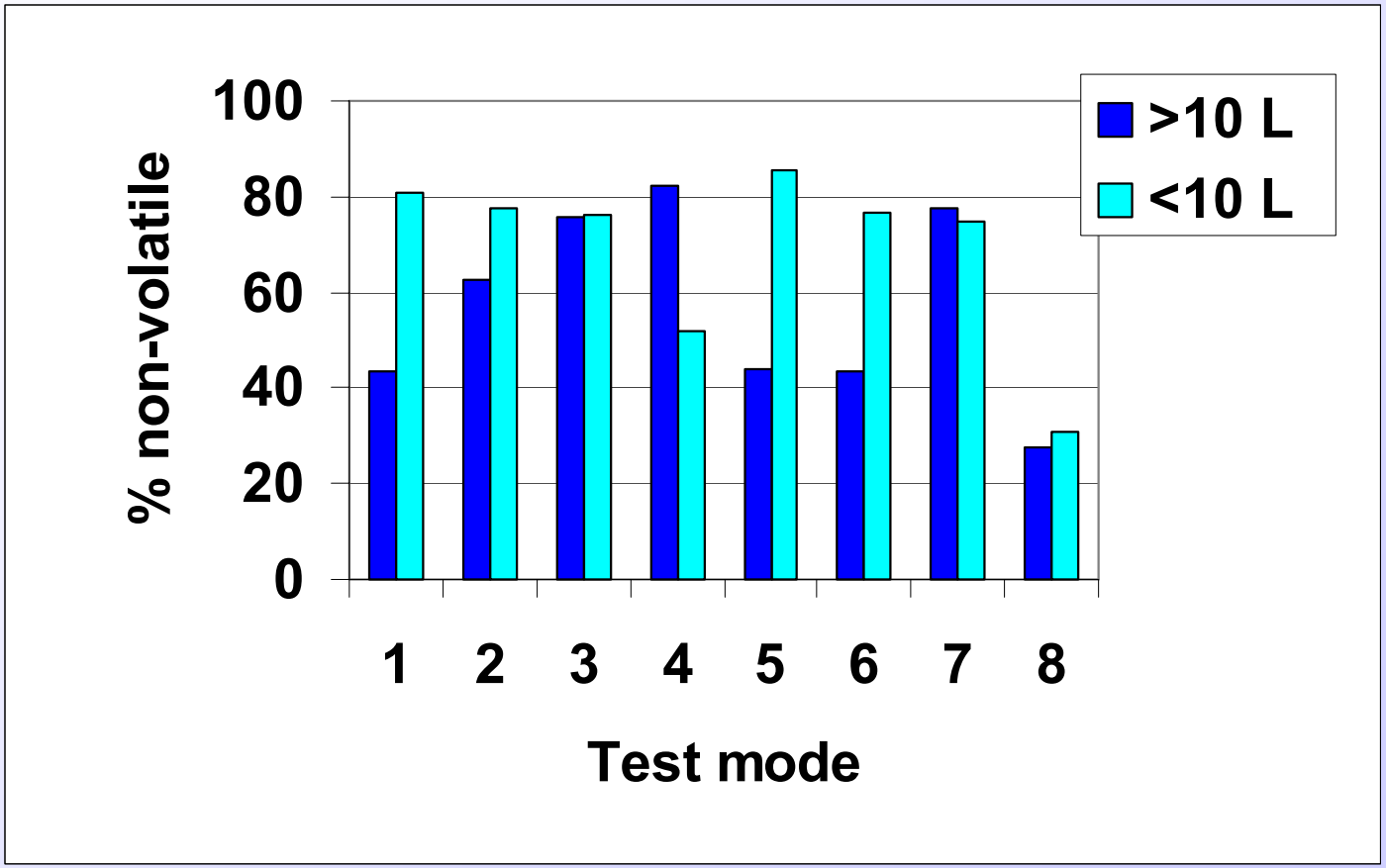
8-mode Weighted Average Non-Volatile PM



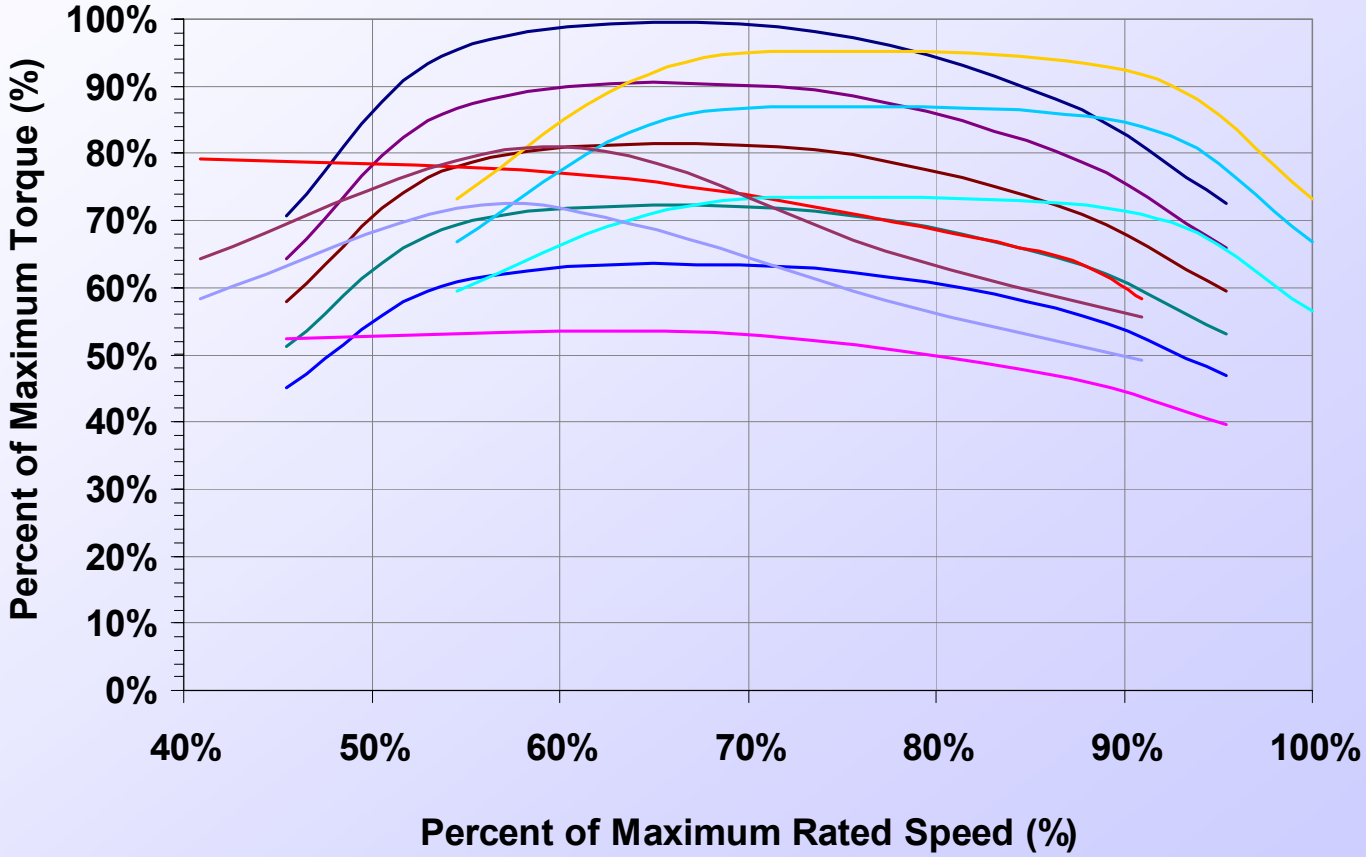
8-mode Weighted Average Non-Volatile PM



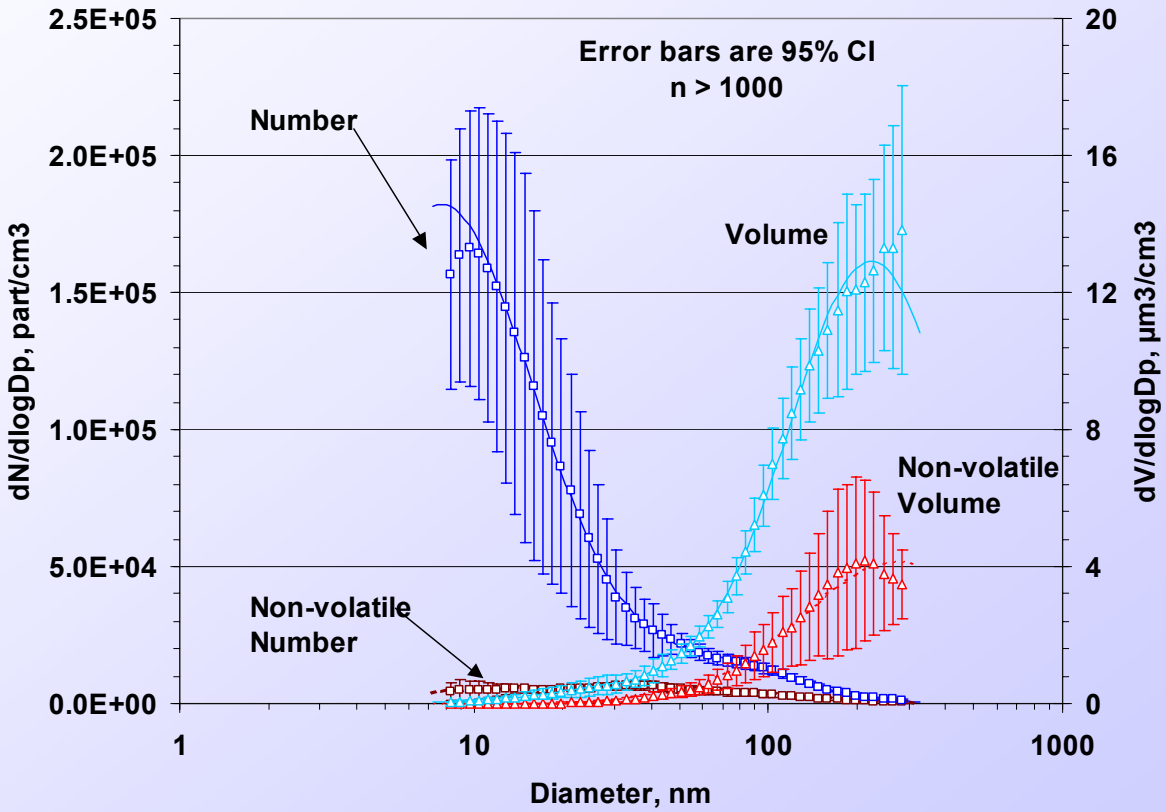
% Non-volatile Tier-2 PM, Per Test Mode



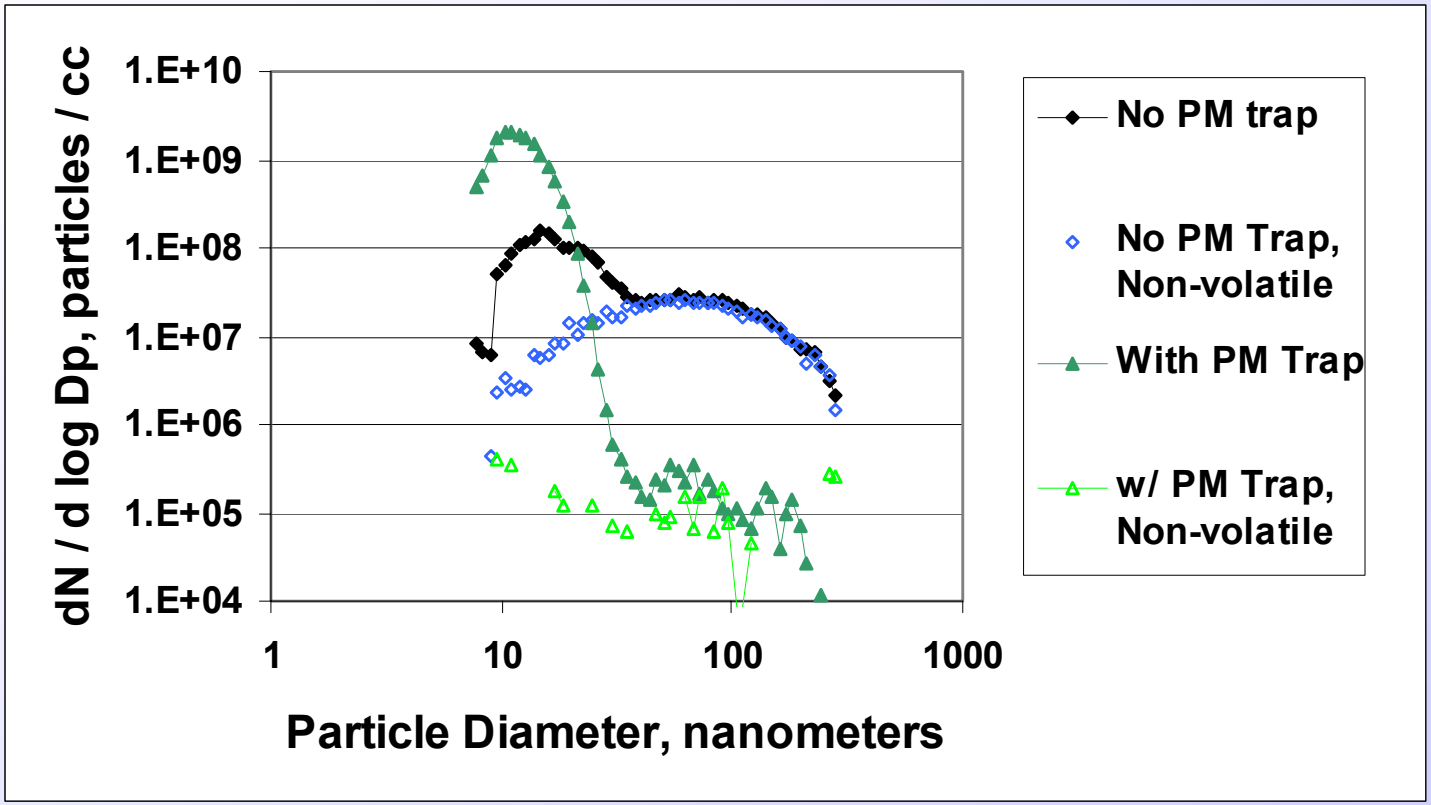
Example of Torque Curve Variety for One Engine Platform



Diesel PM Size Distributions, Measured On-road



Laboratory Dyno Tests of On-road Diesel Engine, w/o Trap, w/ Trap, and Volatiles Removed



Laboratory Dyno Test, Volume Ratios without Exhaust Filter / with Exhaust Filter

- 10 to 40 nm particles
  - All PM = 0.5
  - Non-volatile PM = 200
- 40 to 300 nm particles
  - All PM = 700
  - Non-volatile PM = 1500

Summary and Conclusions

- Gasoline PM decrease, fuel & tech. changes
- Diesel PM decrease w/ 15 ppm S fuel & tech.

- Compared to baseline:
- 2004 On-road diesel PM regs. 90% lower
- 2004 Non-road diesel PM regs. 70% lower
- After 2010, all diesel PM regs. >98% lower

- 30% lower on-road PM inventory in first 8 years
- 20% lower non-road PM inventory in first 8 years

- PM Measurement 1s repeatability, about +/-10%

- On- and non-road PM regs. & inventories converging

- BC amount decreased 70% for Tier-3 engines
- BC decrease 98% for Tier-4 engines