Collaborative Lubricating Oil Study on Emissions (CLOSE) Project

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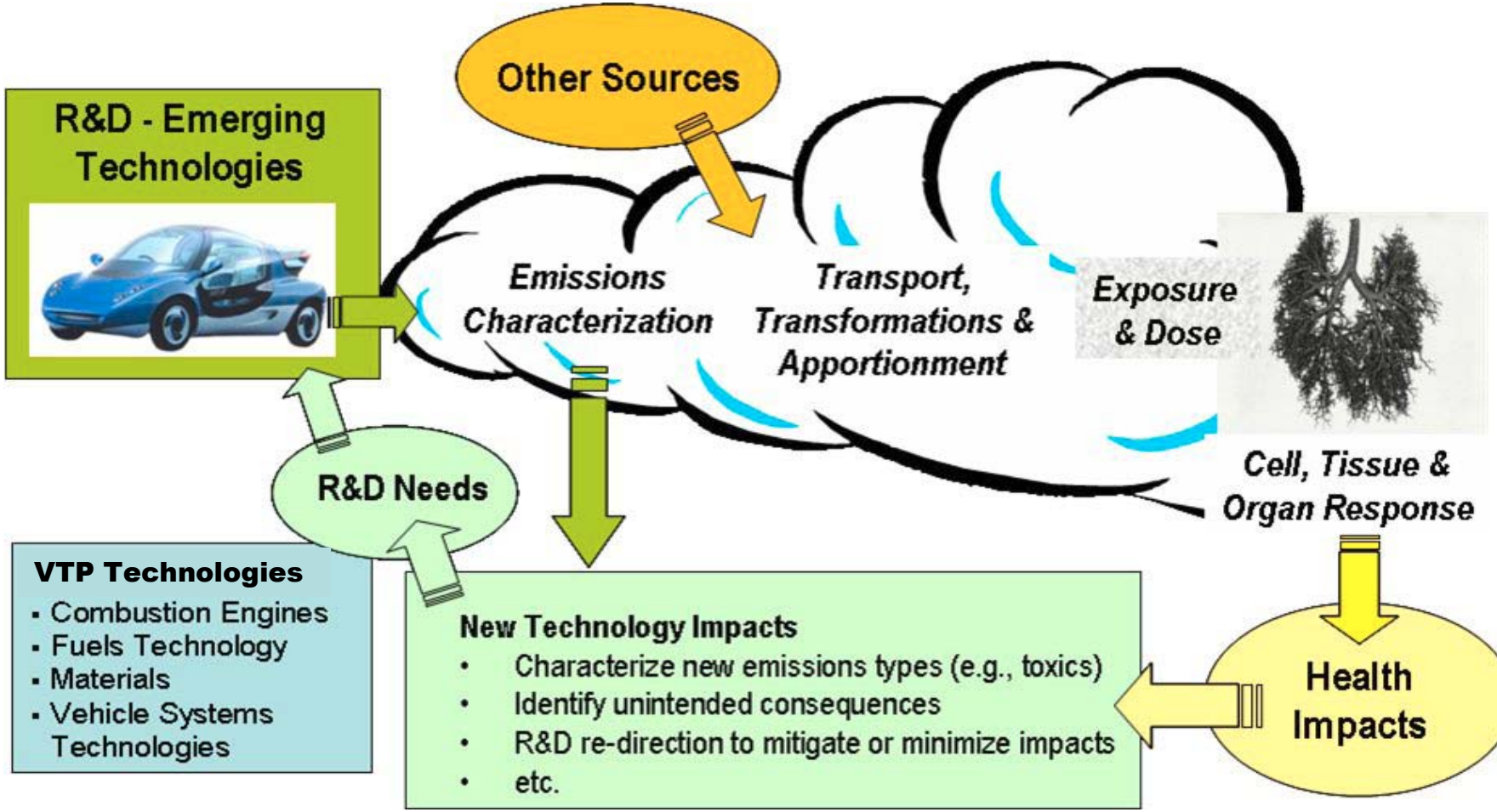
DOE Office of Heavy Vehicle Technologies (OVT)

DOE Office of Vehicle Technologies Health Impacts Effort

- The goals of VT Health Impacts Research Activity are:
  - To provide a sound scientific basis underlying any unanticipated potential health hazards associated with the use of new powertrain technologies, fuels and lubricants in transportation vehicles; and
  - To ensure that vehicle technologies being developed by VT Program for commercialization by industry will not have adverse impacts on human health through exposure to toxic particles, gases, and other compounds generated by these new technologies.

DOE OVT Health Impacts
Research Activity



Collaborative Lubricating Oil Study on Emissions (CLOSE)

Study Objective

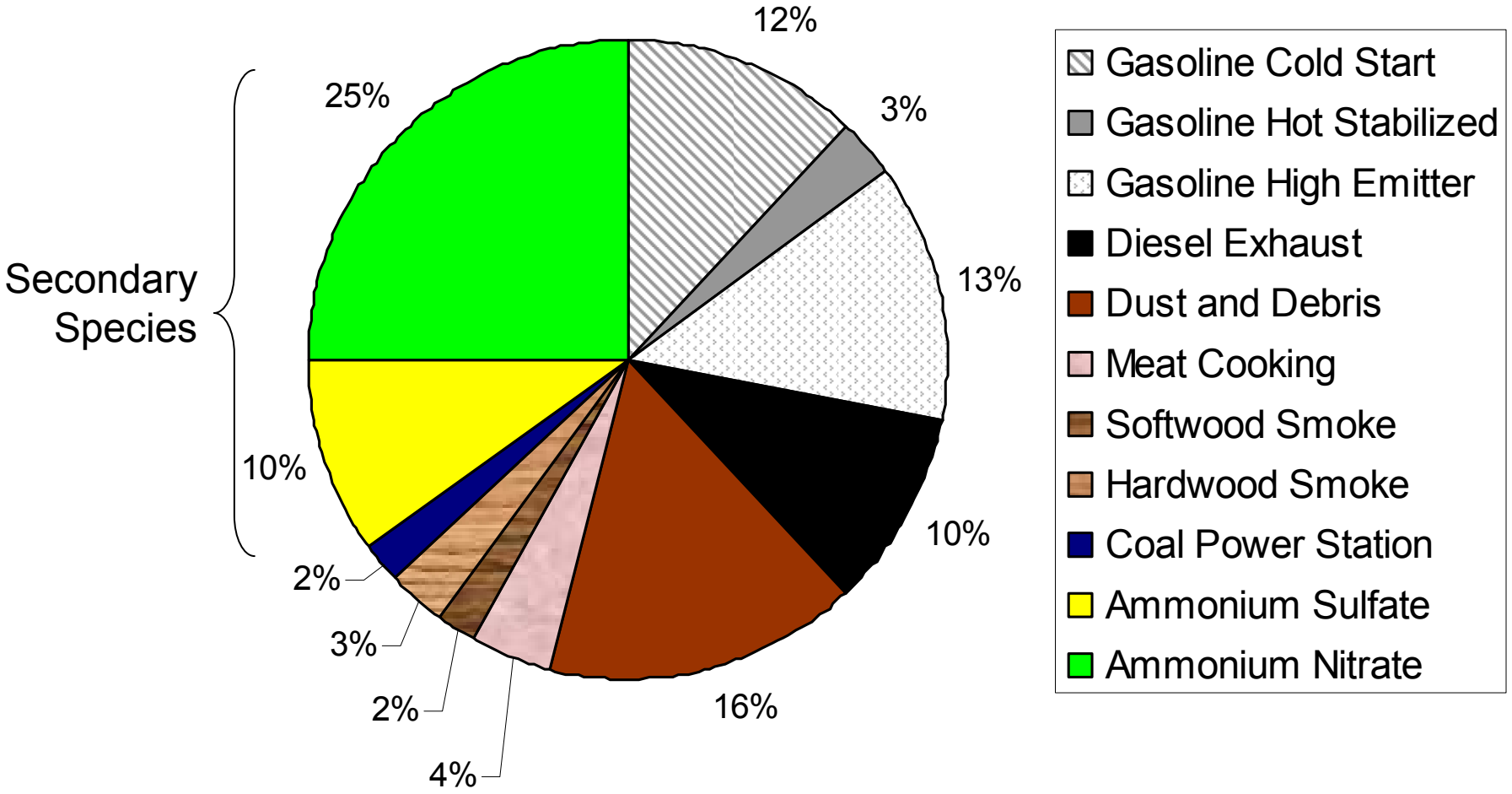
Quantify the relative contributions of fuel and engine lubricating oil to motor vehicle particulate matter (PM) and semivolatile organic compound (SVOC) emissions through extensive chemical and physical characterization of emissions under a variety of engine operating conditions

Why are we doing this?
(We need to pass the "So What" Test)

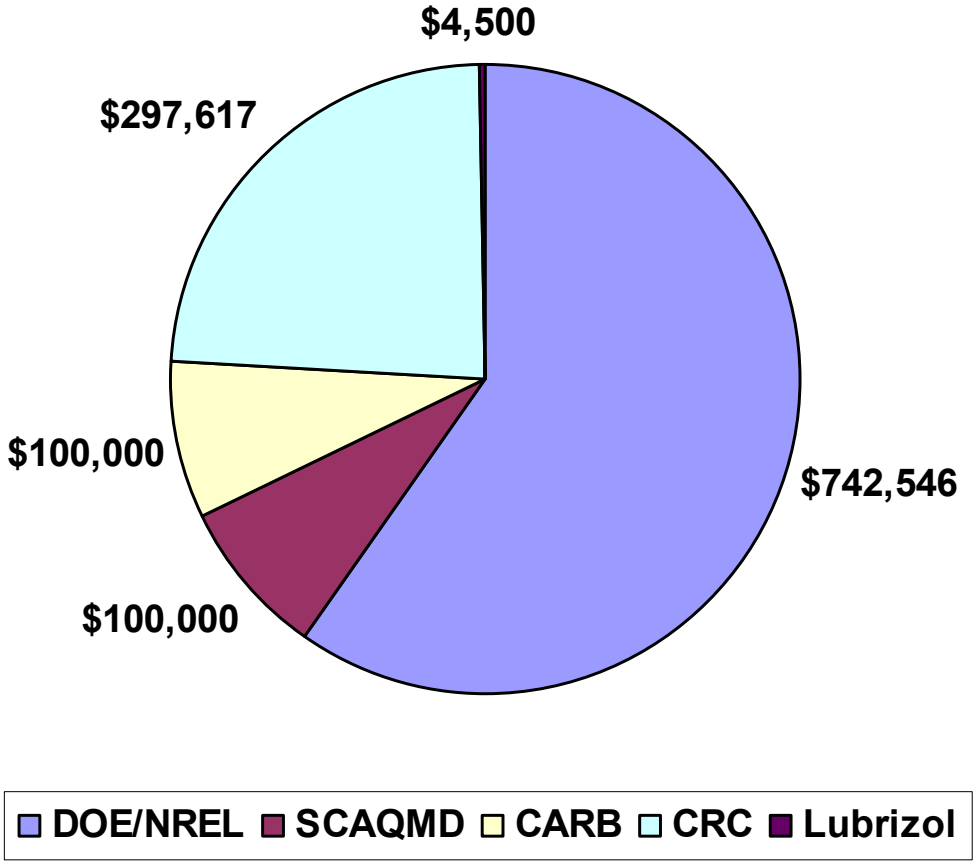
- Source apportionment studies from past 10 years suggest that PM from gasoline engines in urban areas is a more important contributor to ambient PM than PM from diesel engines
  - Denver area [1998, Fujita *et al*. (DRI), NFRAQS]
  - Phoenix area [2003, Lewis *et al*., EPA]
  - Washington, DC [2004, Kim and Hopke, Clarkson U]
  - Los Angeles area [2007, Fujita *et al*. and Schauer *et al*., U WI]
  - Pittsburgh area [2007, Eatough *et al*. BYU]

Northern Front Range Air Quality Study

Denver Welby Monitoring Site, Winter 1996/97, $PM_{2.5}$ Blame Apportionment



CLOSE Financial Support
$1,245,000 (thru April 2008)
Plus all fresh and aged lubricants provided by American Chemistry Council PAPTG members



Test Matrix

Test Temperature	72°F (nominal)				20°F				
Test Lubricant	Fresh		Aged		Fresh		Aged		
Sample Number	1	2	1	2	1	2	1	2	
LD gasoline (normal PM emitter)	✓	✓	✓	✓	✓	✓	✓	✓	Completed
LD gasoline (high PM emitter)	✓	✓	✓	✓	✓	✓	✓	✓	Completed
LD E10 (normal PM emitter)	✓	✓	✓	✓	✓	✓	✓	✓	Completed
LD E10 (high PM emitter)	✓	✓	✓	✓	✓	✓	✓	✓	
MD CARB diesel (normal PM emitter)	✓	✓	✓	✓	✓	✓	✓	✓	
MD CARB diesel (high PM emitter)	✓	✓	✓	✓	✓	✓	✓	✓	
MD B20 biodiesel (normal PM emitter)	✓	✓	✓	✓	✓	✓	✓	✓	
MD B20 biodiesel (high PM emitter)	✓	✓	✓	✓	✓	✓	✓	✓	
HD CNG (normal PM emitter)	✓	✓	✓	✓					
HD CNG (high PM emitter)	✓	✓	✓	✓					
HD CARB diesel (normal PM emitter)	✓	✓	✓	✓					
HD CARB diesel (high PM emitter)	✓	✓	✓	✓					

LD Driving Cycle: California Unified Cycle (LA-92)
HD Driving Cycle: EPA HD Urban Dynamometer Driving Schedule (heavy duty chassis cycle)

Test Oils for CLOSE Study – Oil Performance and Aging

- American Chemistry Council Petroleum Additives Product Approval Protocol Task Group (PAPTG) and Coordinating Research Council Lubricant Panel developed test oil matrix
- Lubricants supplied by ACC PAPTG members
- Each lubricant doped with $C_{36}D_{74}$ tracer to label lubricant contribution to emissions

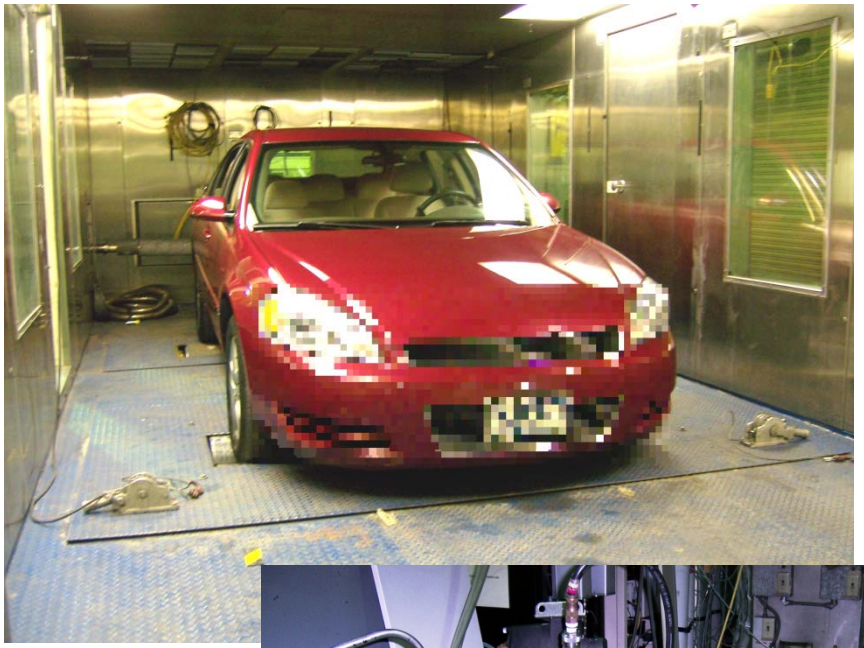
	LD Gasoline / E10 Oil	MD Diesel / Biodiesel Oil	HD CNG Oil	HD Diesel Oil
Performance Level	APISM/ ILSAC GF-4	Cummins CES 20074/DDC 7SE272	API CJ-4/SM	API CJ-4
Viscosity Grade	5W20	15W40	15W40	15W40
How Aged Oil Is Generated	2.7 L to 4.6 L Detroit OEM vehicles with oil drain interval of 7.5K and 10K miles	CNG City Bus Service, ~ 60K mi/yr, 6K drain interval. Engines are DDC Series 50s and John Deere CNG	HD diesel line service running 50% of the time at 80,000 GVW. Drain interval is 25K mi. Engines are 2006 CAT C-15s and Cummins ISX	HD Mack Class 8 trucks over the road 80,000 GVW max. Drain intervals 20K-30K mi.

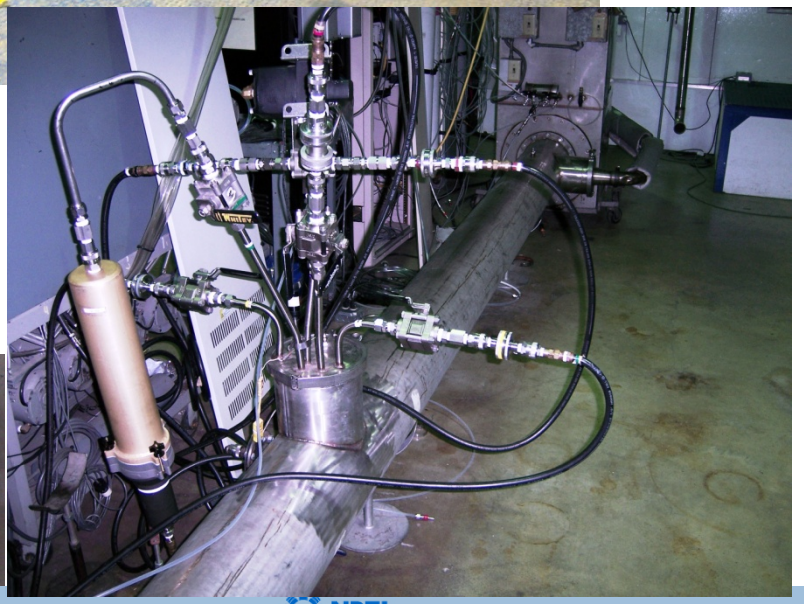
Test Fuels: LD Normal Emitter

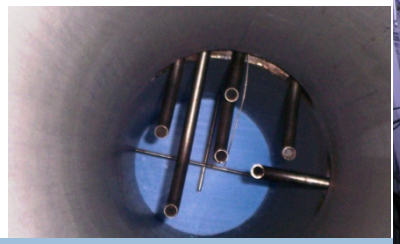
- Testing at 72°F
  - Gasoline: similar to California Phase 3 fuel but not oxygenated
  - E10: CA RFG Phase 3 certification fuel splash-blended with additional ethanol
- Testing at 20°F
  - Gasoline: cold CO certification fuel
  - E10: cold CO fuel splash-blended with ethanol

Normal Emitter LD Gasoline Vehicle Testing

- LD normal emitter testing completed
  - 2006 model year with 3.5L V6 engine
  - 30,695 miles on odometer
  - Among the top-selling passenger cars in CY2006
  - Based on previous experience, expected PM emission rate > 0.6 mg/mi
- Performed follow-on testing with E0 at room temperature to check for vehicle and system drift; also collected ultrafine particles by size for chemical analysis
- Testing performed at Southwest Research Institute; chemistry performed at SwRI, Desert Research Institute, and Elemental Analysis Inc.







Sampling and Analyses

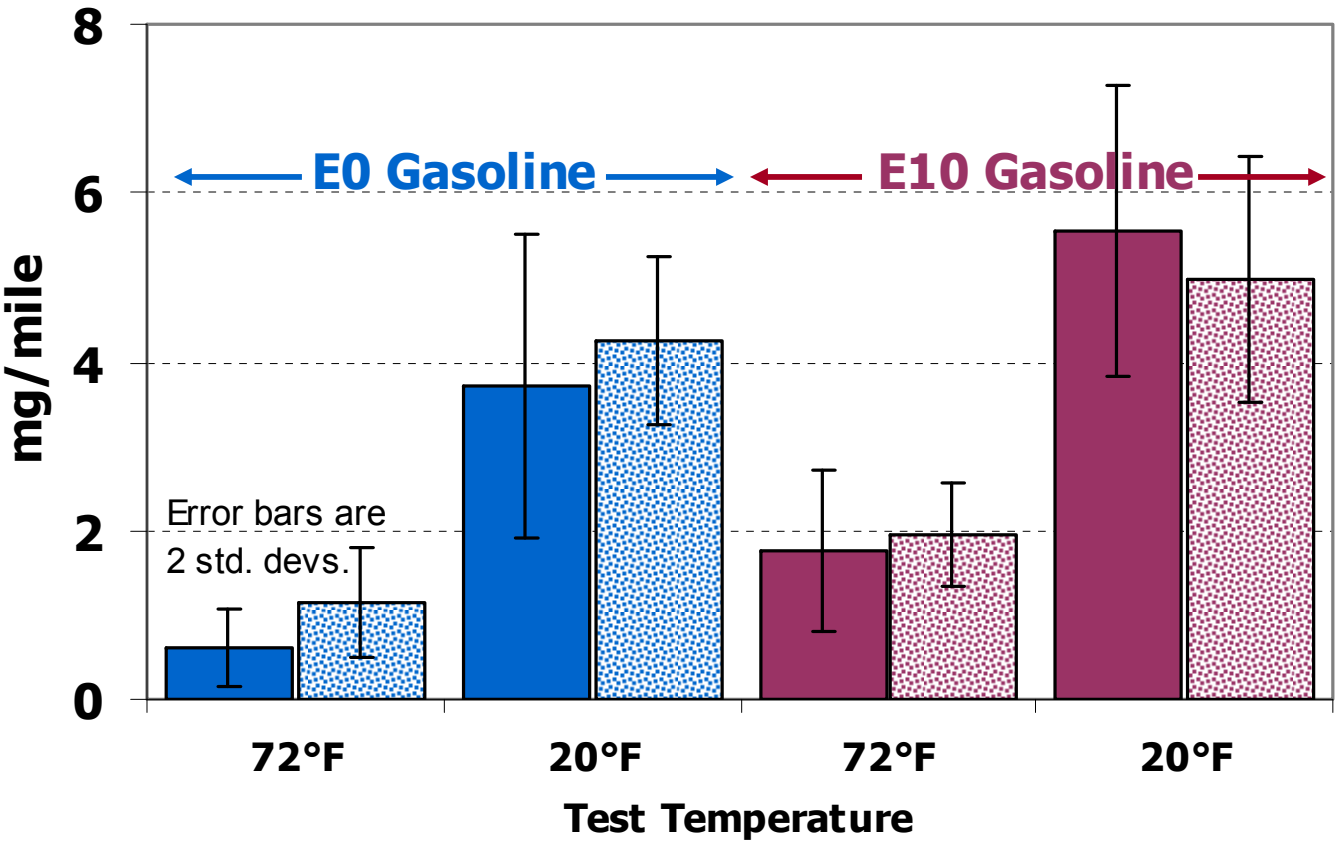
- PM mass emission rate (gravimetric)
- Real-time particle count by EEPS; three measurements were taken in the following order:
  - Total PM (solid & volatile)
  - Solid PM
  - Total PM
- Additional analyses not presented today:
  - Regulated gaseous emissions
  - PM
    - Elements (including lube oil markers)
      - energy dispersive X-ray fluorescence (EDXRF) and proton induced X-ray emission (PIXE) analysis
      - inductively coupled plasma-mass spectrometry (ICPMS) for subset of 18 elements
    - Hopanes and steranes by GC/MS
    - "Elemental" and "organic" carbon by TOR/TOT
    - Soluble organic fraction by extraction
    - Sulfate by ion chromatography
    - PAHs by GC/MS
    - C_{14} to C_{40} alkanes & cycloalkanes by CG/MS
  - Semi-volatile organic constituents by GC/MS
  - Deuterated alkane ($C_{36}D_{74}$) as lube oil tracer by GC/MS

Preliminary Data/Testing in Progress

Data shown are for one vehicle only, may change before final analyses, and may not represent the fleet at large!

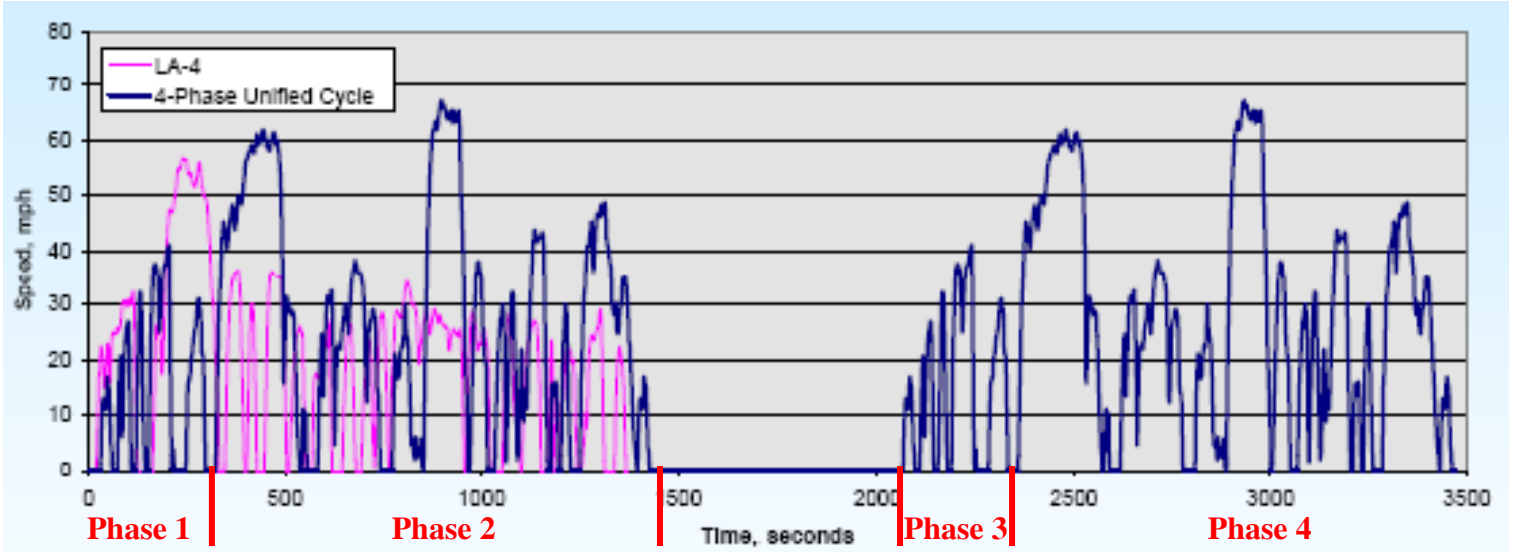
PM from Normal Emitter Gasoline LD Vehicle

Unified Driving Cycle (Ave. of 16 UDCs at 72°F and 4 UDCs at 20°F)



Fresh Oil = Solid Color; Aged Oil = Confetti

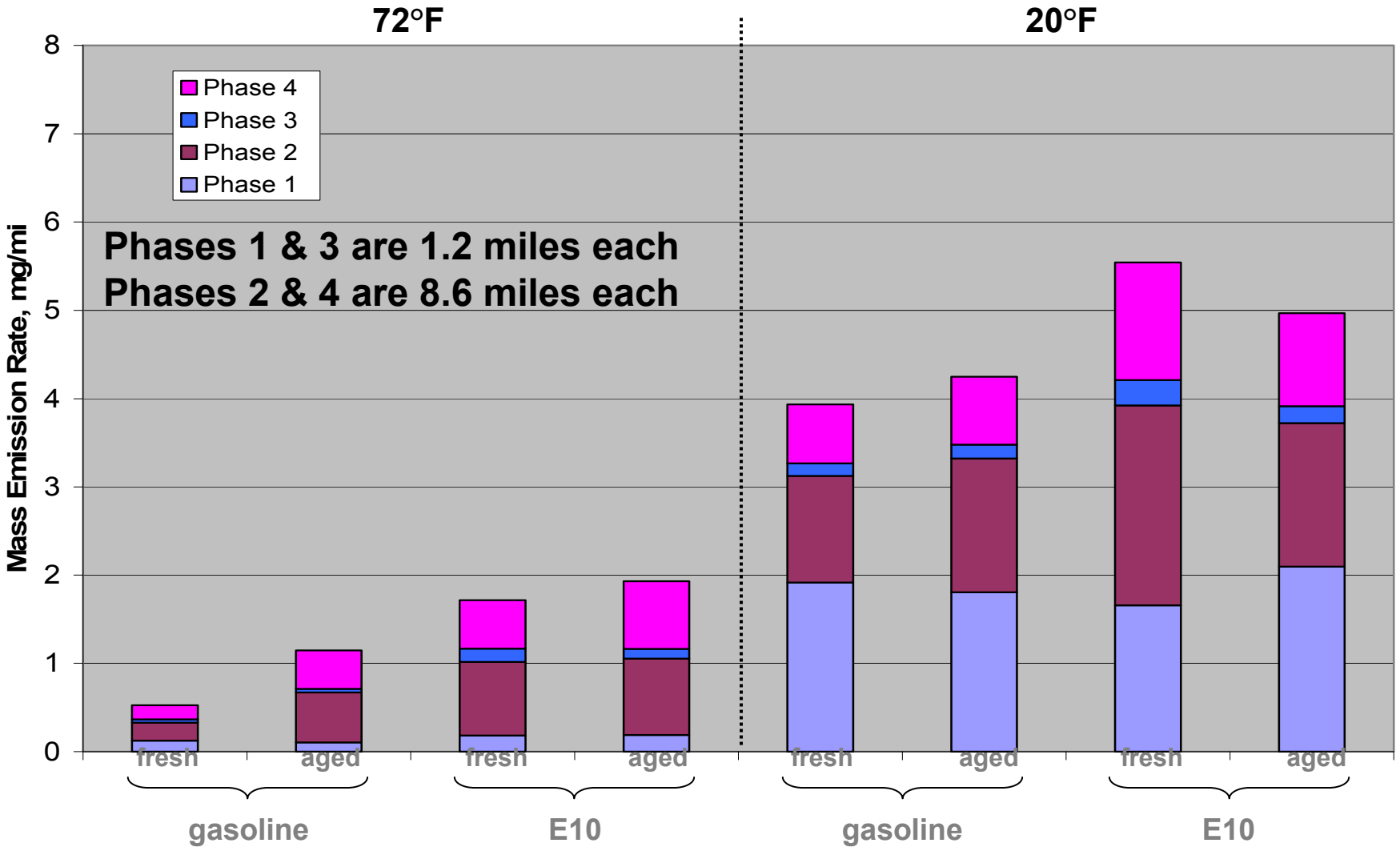
Four-Phase Unified Driving Cycle vs. LA-4 Test Cycle



For normal emitter:

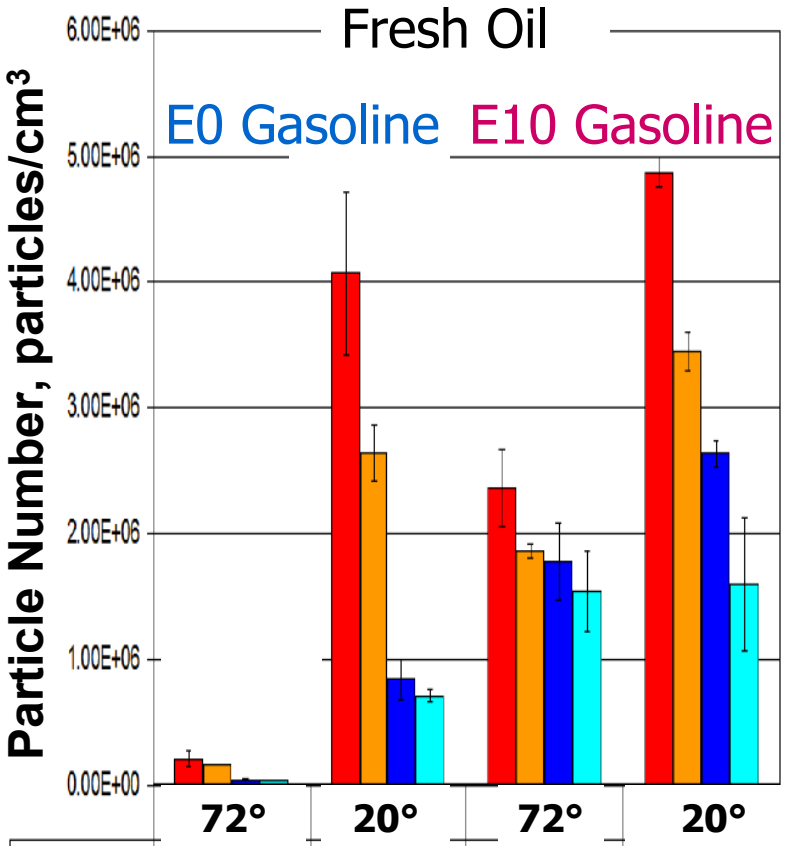
- 72°F: 8 consecutive cold-start tests per sample
- 20°F: 2 consecutive cold-start tests per sample

Weighted PM Contribution by Test Phase

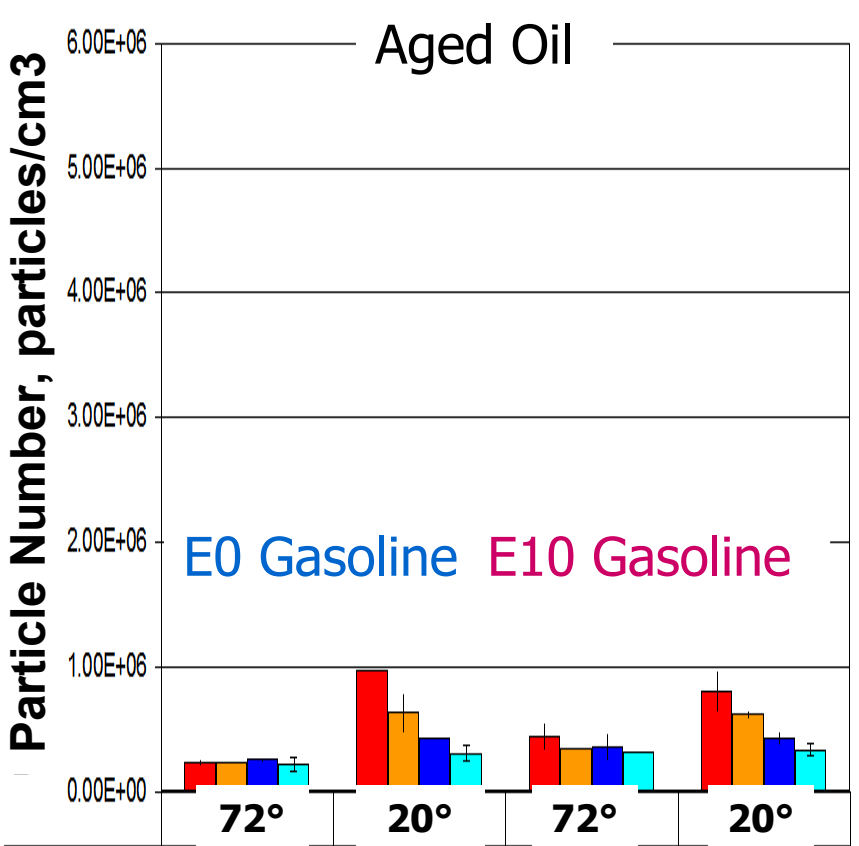


Particle Number Distribution

Normal Emitter Gasoline LD Vehicle



	72°	20°	72°	20°
Cold Start-Total	2.09E+05	4.06E+06	2.36E+06	4.87E+06
Cold-Start-Solid	1.57E+05	2.64E+06	1.86E+06	3.44E+06
Hot Start-Total	4.15E+04	8.41E+05	1.78E+06	2.64E+06
Hot-Start-Solid	3.97E+04	7.09E+05	1.53E+06	1.60E+06



	72°	20°	72°	20°
Cold Start-Total	2.39E+05	9.71E+05	4.43E+05	8.01E+05
Cold-Start-Solid	2.30E+05	6.36E+05	3.44E+05	6.20E+05
Hot Start-Total	2.58E+05	4.34E+05	3.64E+05	4.26E+05
Hot-Start-Solid	2.24E+05	3.09E+05	3.20E+05	3.38E+05

Conclusions from CLOSE Project

- None today; all data preliminary.
- Study in progress at present time; partial data from only one normal-emitting gasoline LD vehicle presented; high emitter LD vehicle has been recruited and testing is in progress. Results will be available latter part of 2009.
- The data shown here are from only one vehicle and may not be represent the entire normal-emitting LD fleet.