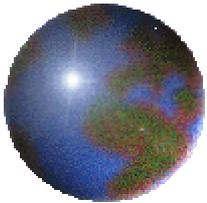




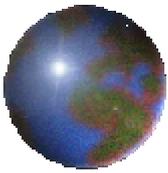
2002 DEER Conference



San Diego, California

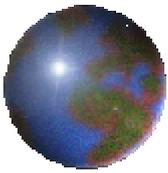
Dave Smith - bp

August 25th - 29th, 2002



INVESTIGATION OF THE EFFECTS OF FUELS AND AFTERTREATMENT DEVICES ON THE EMISSION PROFILES OF TRUCKS AND BUSES

- Miriam Lev-On, Chuck Le Tavec, Jim Uihlein, Ken Kimura, BP;
- Teresa L. Alleman, Douglas R. Lawson, Keith Vertin, NREL;
- Gregory J. Thompson, Mridul Guatam, Scott Wayne, WVU;
- Barbara Zielinska, John Sagebiel, DRI;
- Sougato Chatterjee, Johnson Matthey; and
- Kevin Hallstrom, Engelhard Corporation.



ECD Demonstration Program

Participants

◆ **Agencies**

■ National

- DOE and NREL major supporter & working group member
- EPA review and comment on test program

■ California

- CARB, SCAQMD and CEC are members of working group

◆ **Academia**

■ West Virginia University

■ University of California, Riverside

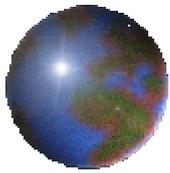
■ Desert Research Institute

◆ **Industry**

■ Engelhard and Johnson-Matthey with support from Corning, NGK-Lock and Fleetguard Nelson

■ Cummins, Detroit Diesel, Ford and International

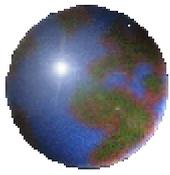
◆ **Fleet operators**



Fuel Analysis Results

1st Round of testing Test Fuel Properties (1 Sample)

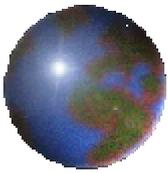
<u>Property</u>	<u>CARB</u>	<u>ECD</u>	<u>ECD-1</u>
Cetane Number	54.1	64.7	51.3
Sulfur, ppm	121	7.4	13.1
SFC Aromatics			
Total, vol%	22.5	10.9	23.8
PNA, wt%	4.1	0.9	2.8



ECD Demonstration Program

Fleet Participants

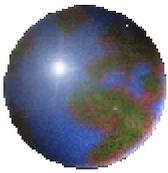
	ECD w/ Johnson Matthey	ECD w/ Engelhard	ECD with original muffler	CARB w/ original muffler	Total
ARCO	5	5	9	10	29
San Diego Schools	5	5	10	10	30
LA City	5	5	2	3	15
LA MTA	2		8	8	18
Tram vehicles	5	0	15		20
Hertz Equipment Rental	5	5	5	5	20
Ralphs Grocery	5	5	5	5	20
Total	32	25	54	41	152



San Diego School Buses

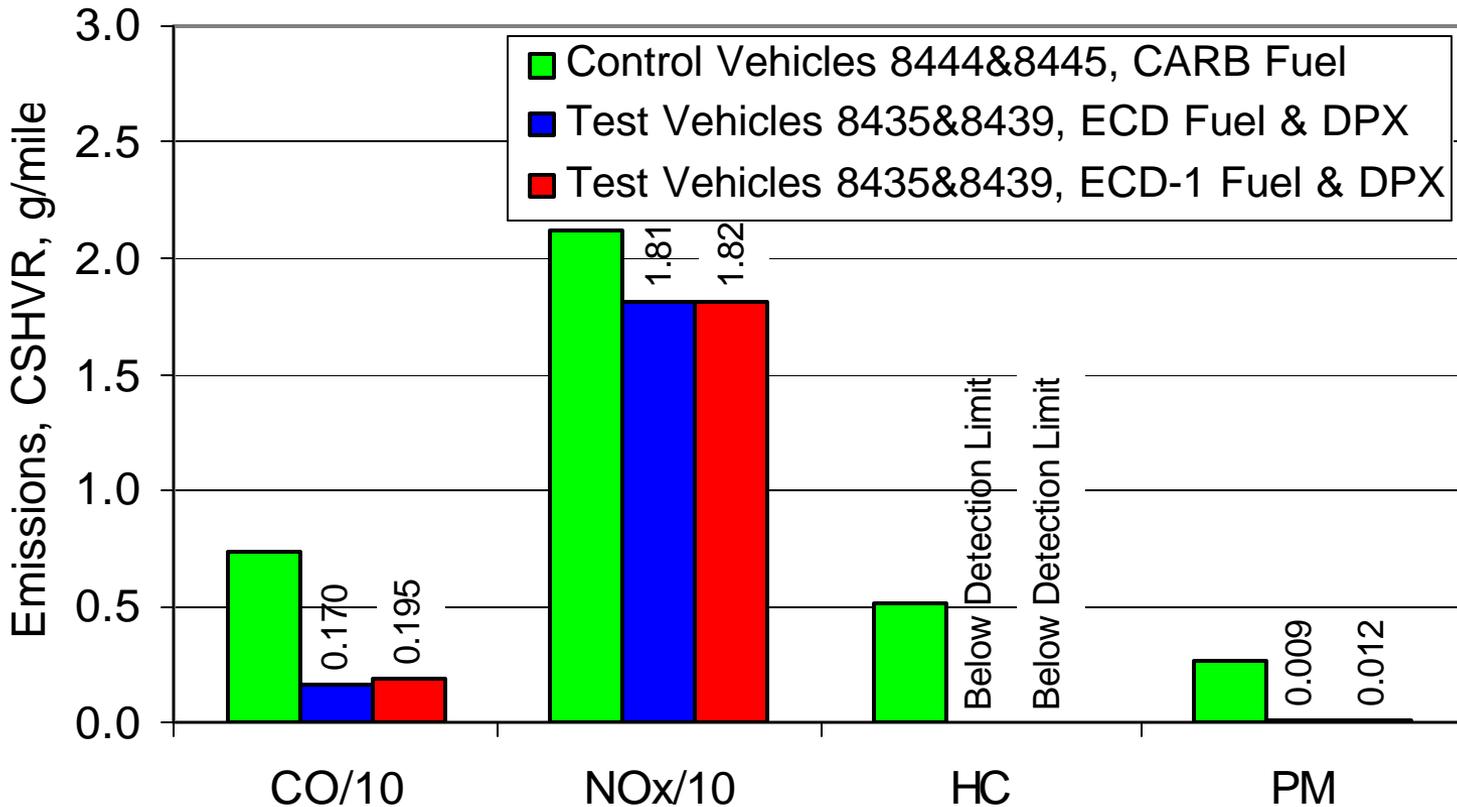


- ❖ 1998 American Transportation 3000RE International Chassis
- ❖ International 530 E 8.7 liter I6 turbo, 275hp
- ❖ Automatic transmission, 5 speed
- ❖ Engelhard DPX catalyzed soot filter
- ❖ 32,200 lb test weight

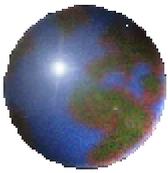


Effect of ECD and ECD-1 Fuels

School Buses with DPX Filters



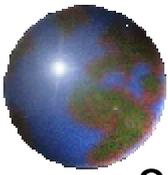
- CO, HC and PM emissions were about the same, indicating the oxidative performance of the DPX was about the same with either fuel



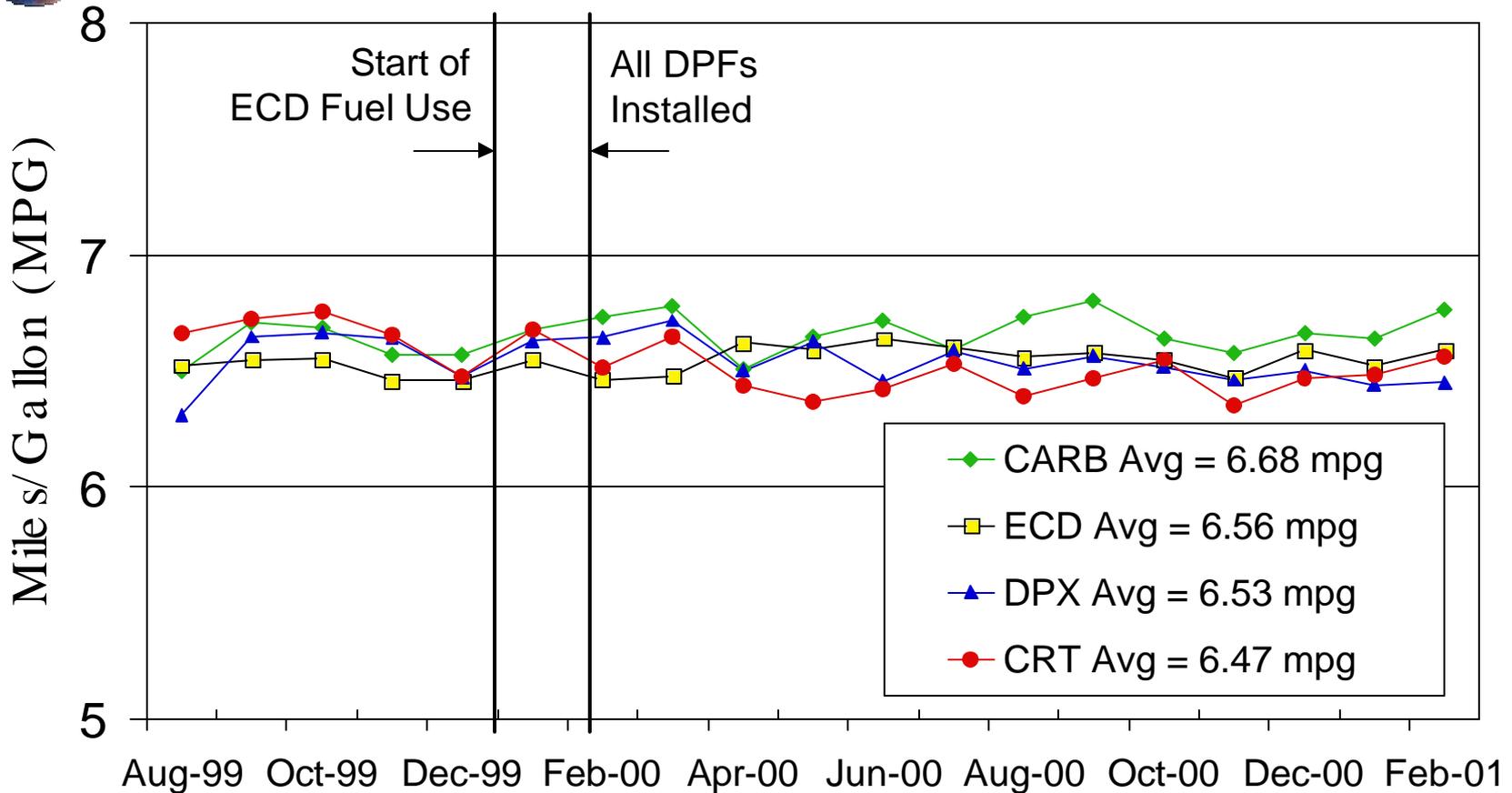
Ralphs Grocery Trucks



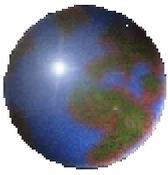
- ❖ **1999 Sterling L-line Chassis**
- ❖ **1998 Detroit Diesel series 60**
- ❖ **12.7 liter turbocharged diesel, 430hp**
- ❖ **10 spd. Manual transmission**
- ❖ **Johnson Matthey CRT and Engelhard DPX**
- ❖ **42,000 lb test weight**
- ❖ **Twenty trucks tested to investigate vehicle-to-vehicle variability**



Grocery Truck Monthly Fuel Economy



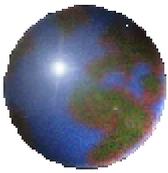
- Small average MPG differences attributed to lower energy density of ECD fuel
- Energy density difference for ECD-1 and typical California diesels is negligible



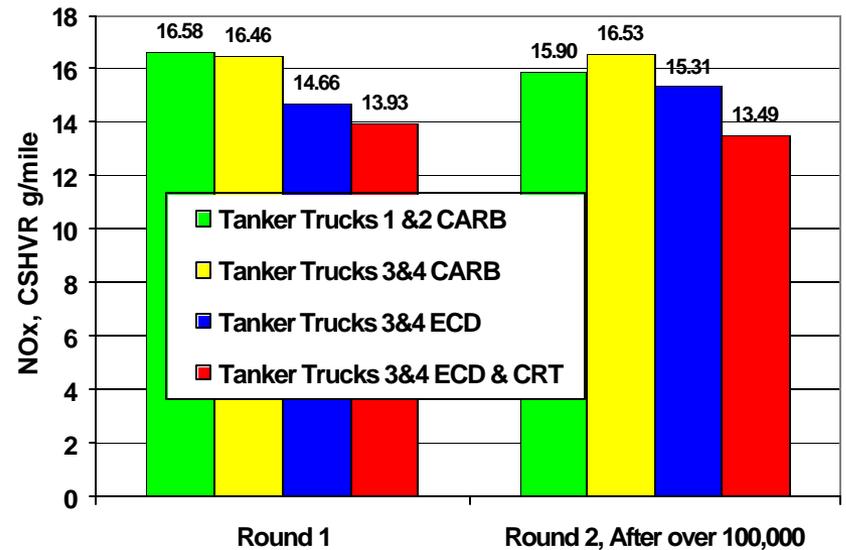
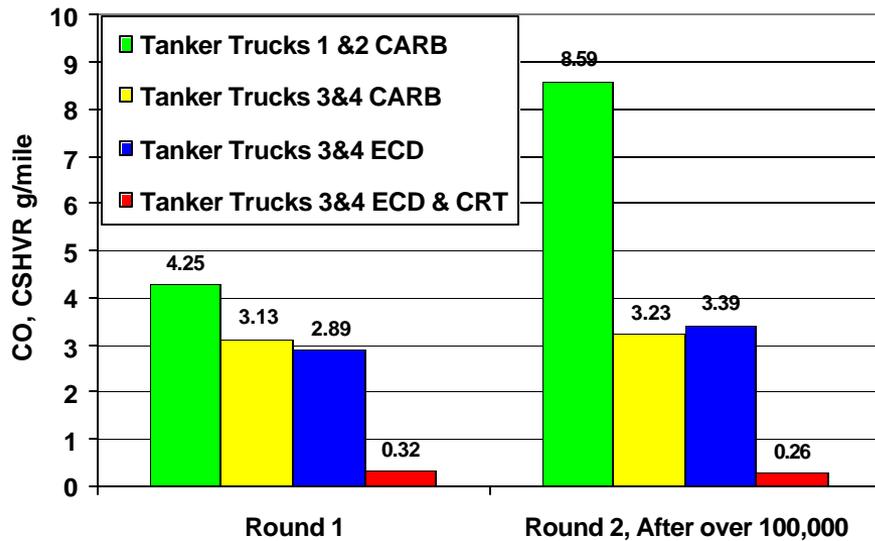
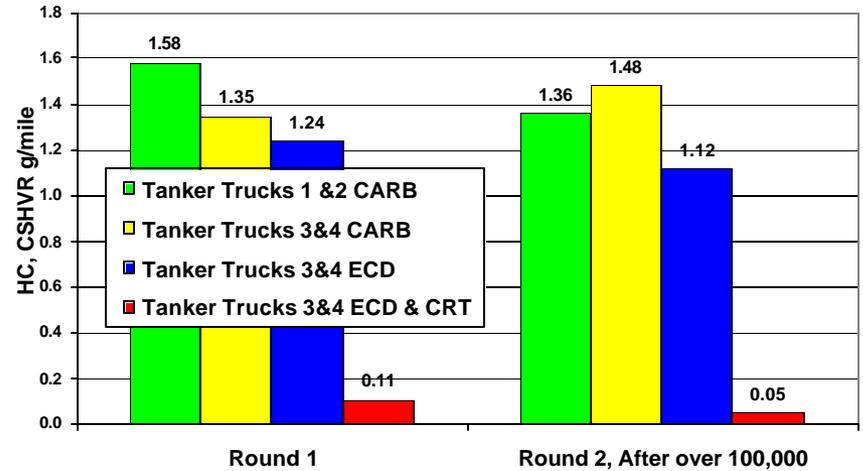
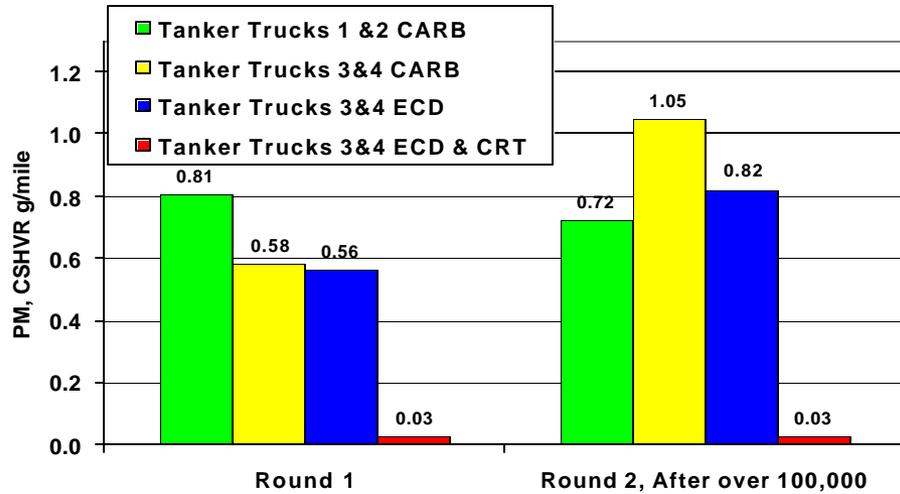
ARCO Tanker Trucks

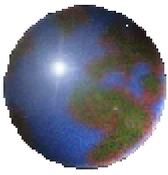


- ❖ Kenworth chassis
- ❖ 1995 & 96 Cummins M11 10.8 litre turbocharged diesel, 330hp
- ❖ 10 spd. Manual transmission
- ❖ Johnson Matthey CRT
- ❖ 32,200 lb test weight



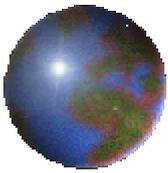
ARCO Tanker Trucks





Speciation Data

LA MTA Transit Bus Example



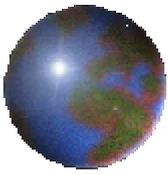
LA MTA Transit Buses

❖ **1998 Diesel New Flyer Transit Bus**

- ❖ **Detroit Diesel Series 50**
- ❖ **8.5 Liter, 275 hp**
- ❖ **5 Speed Automatic Transmission**
- ❖ **Johnson Matthey CRT**

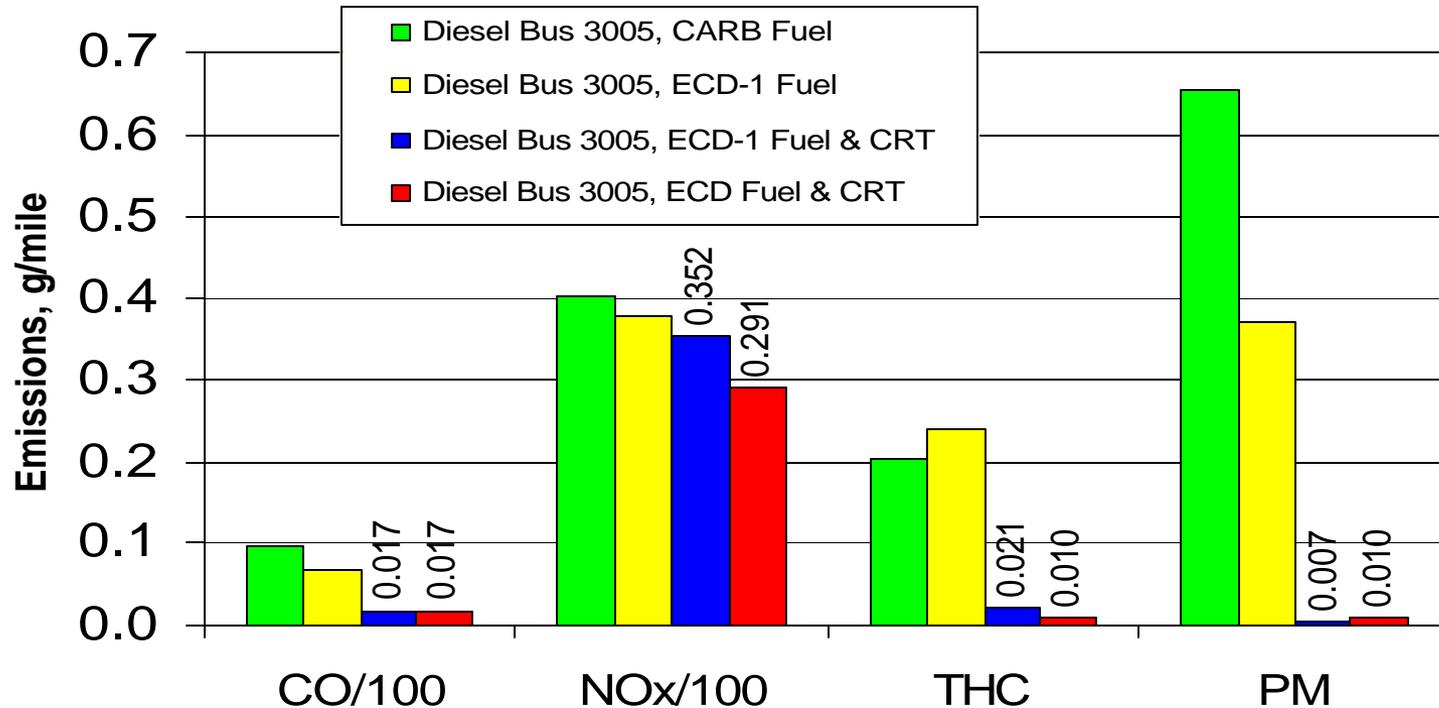
❖ **2000 and a 2001 CNG New Flyer Transit Bus**

- ❖ **Detroit Diesel Series 50 G**
- ❖ **8.5 Liter, 275 hp**
- ❖ **5 Speed Automatic Transmission**
- ❖ **Close Loop Control**
- ❖ **No aftertreatment – Compliant with Current State and Local Rules**

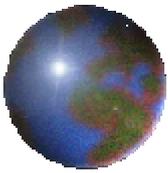


Effect of ECD and ECD-1 Fuels Transit Buses with CRT Filters

Round 2 Diesel Transit Bus Emissions, CBD(2)



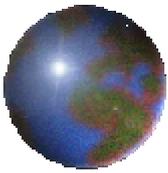
- CO, HC and PM emissions were about the same, indicating the oxidative performance of the CRT was about the same with either fuel



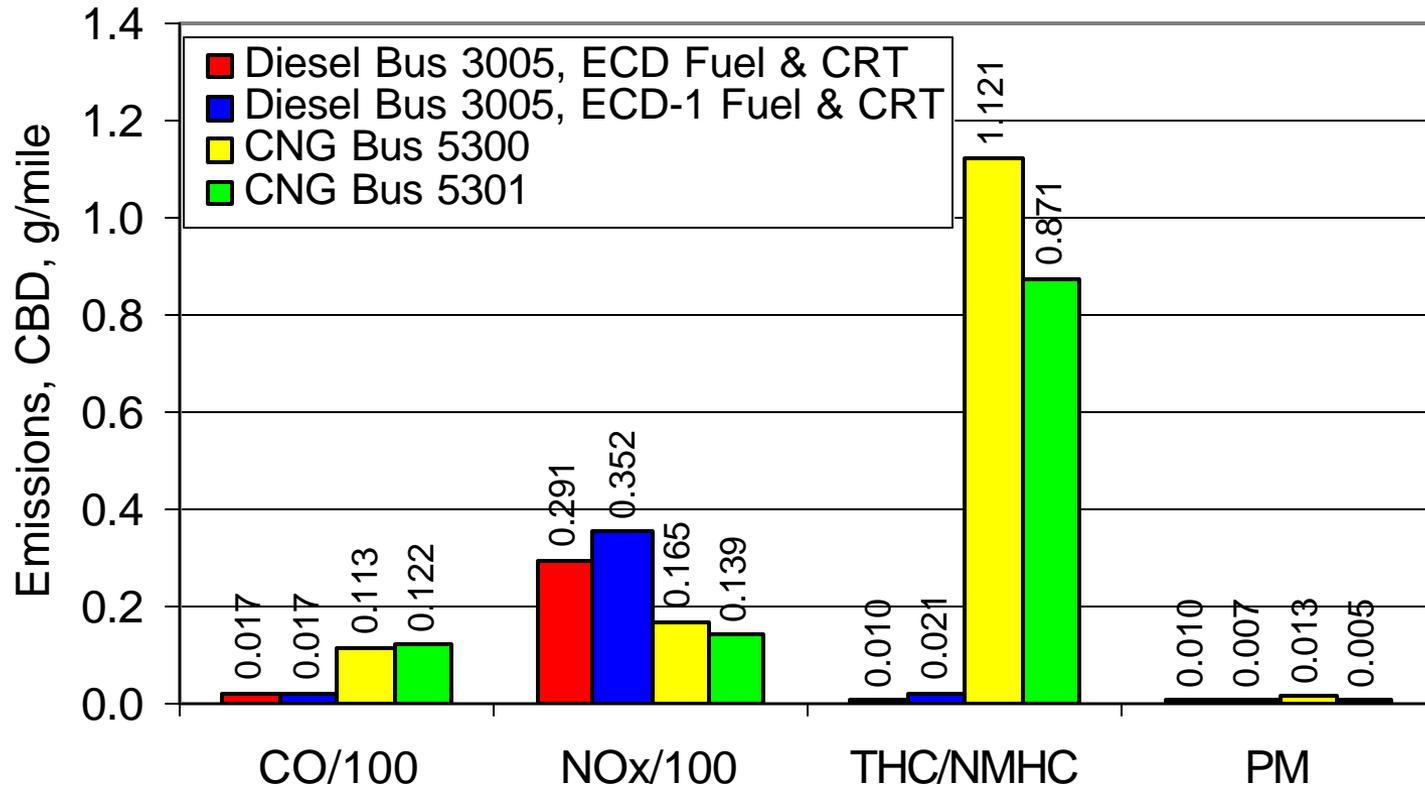
Speciation Testing

- Special speciation test plan was developed
 - enhanced emissions sampling
 - allow detailed analytical characterization
 - particle sizing analysis of the exhaust
- Goals to study what impact fuels and passive catalyzed particulate filters have on:
 - unregulated toxic emission species
 - particle size distribution
 - mutagenicity – still awaiting results

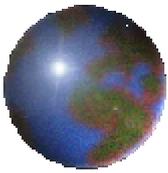
Note: Diesel engines without filters were fitted with a standard muffler with no oxidation catalyst.



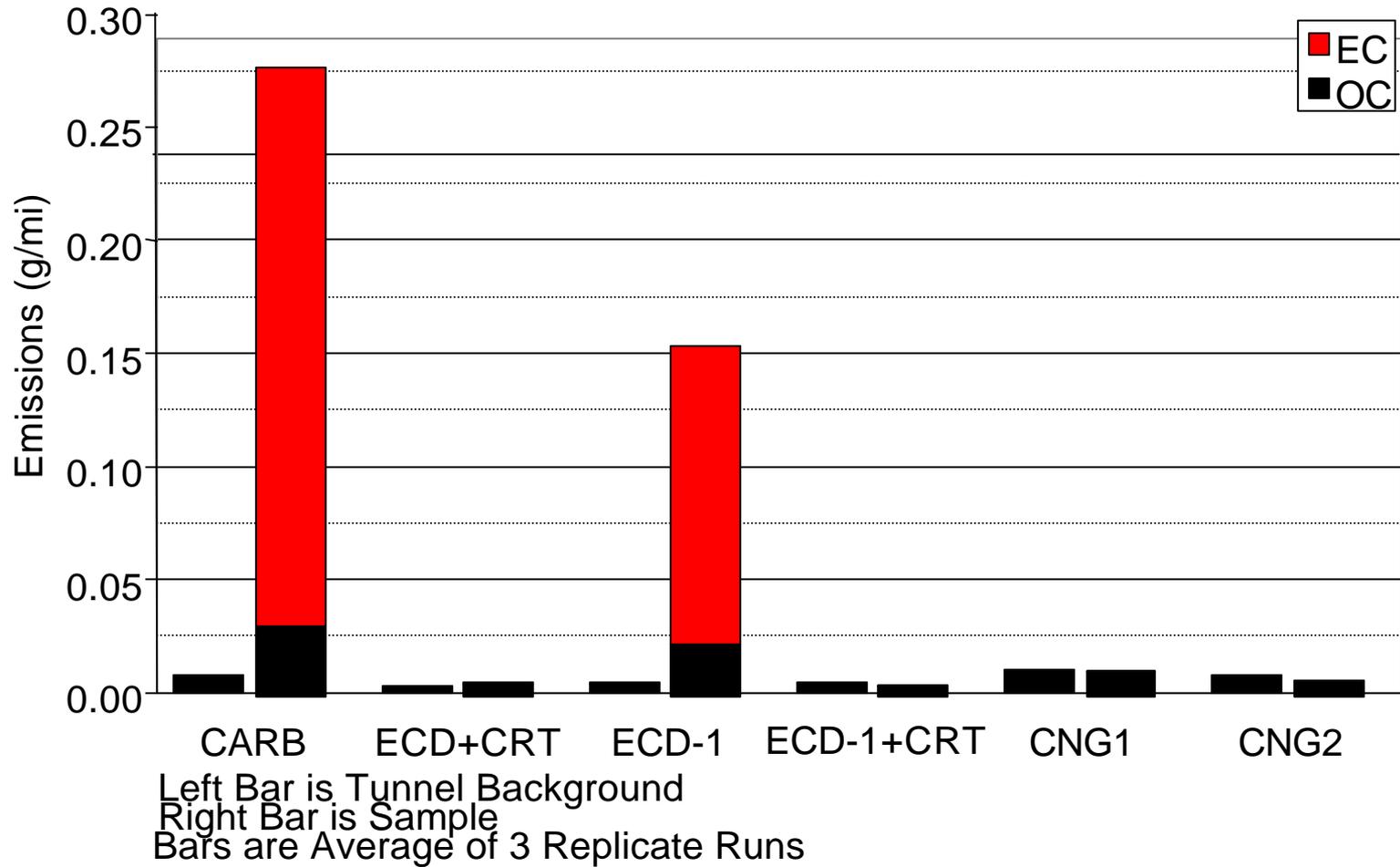
Diesel vs. CNG Comparison

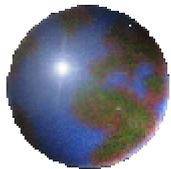


- Note: Total hydrocarbons presented for retrofitted diesel bus, non-methane hydrocarbons presented for CNG buses



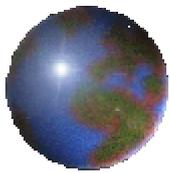
Elemental and Organic Carbon



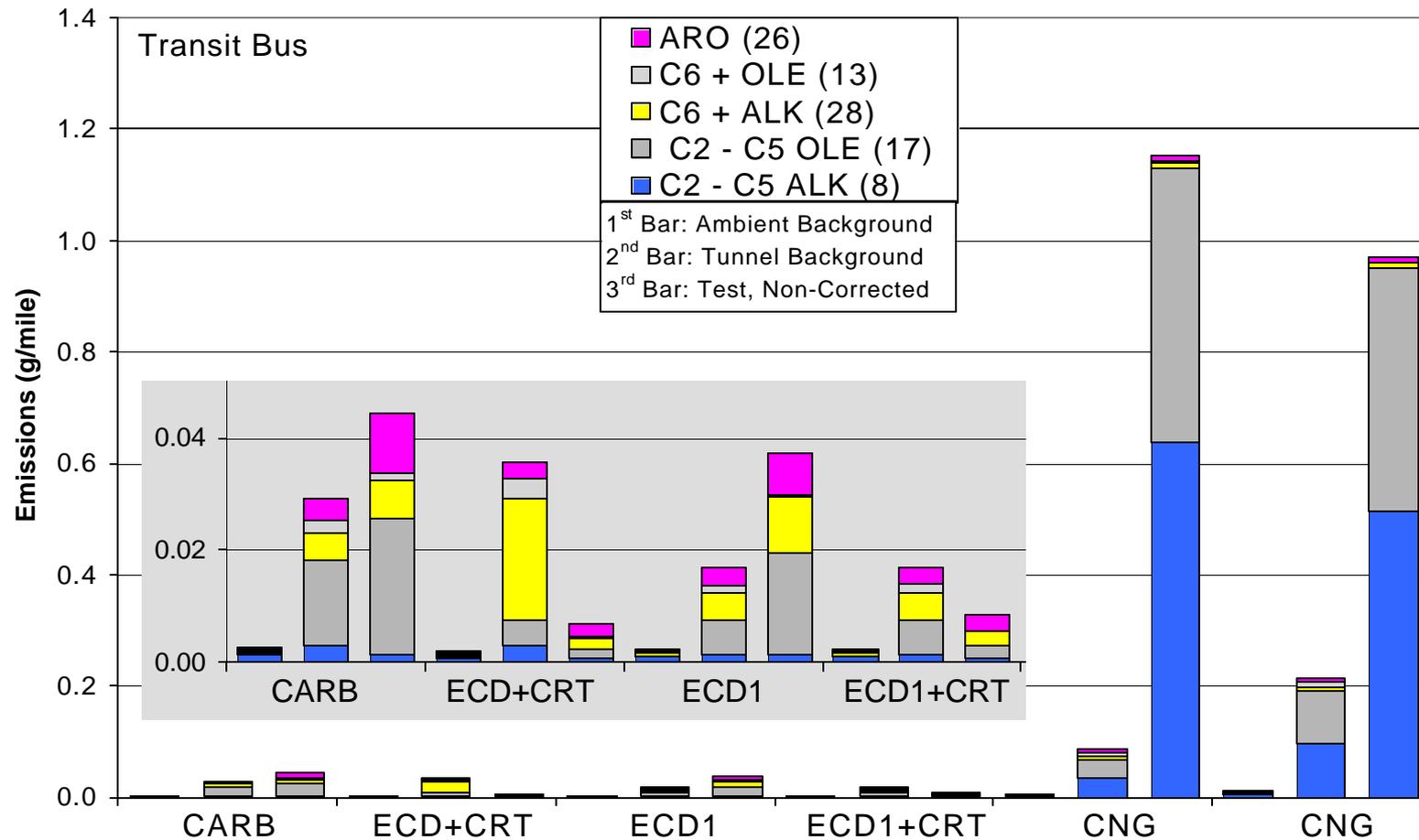


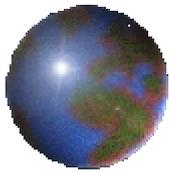
Volatile Organic Compounds

- ✦ nMHC clustering
 - ▣ 95 individual compounds identified
 - ▣ Hydrocarbon chains with $C_2 - C_{11}$
- ✦ Five compound classes defined
 - ▣ $C_2 - C_5$ Alkanes
 - ▣ $C_2 - C_5$ Olefins
 - ▣ C_{6+} Alkanes
 - ▣ C_{6+} Olefins
 - ▣ $C_6 - C_{11}$ Aromatics

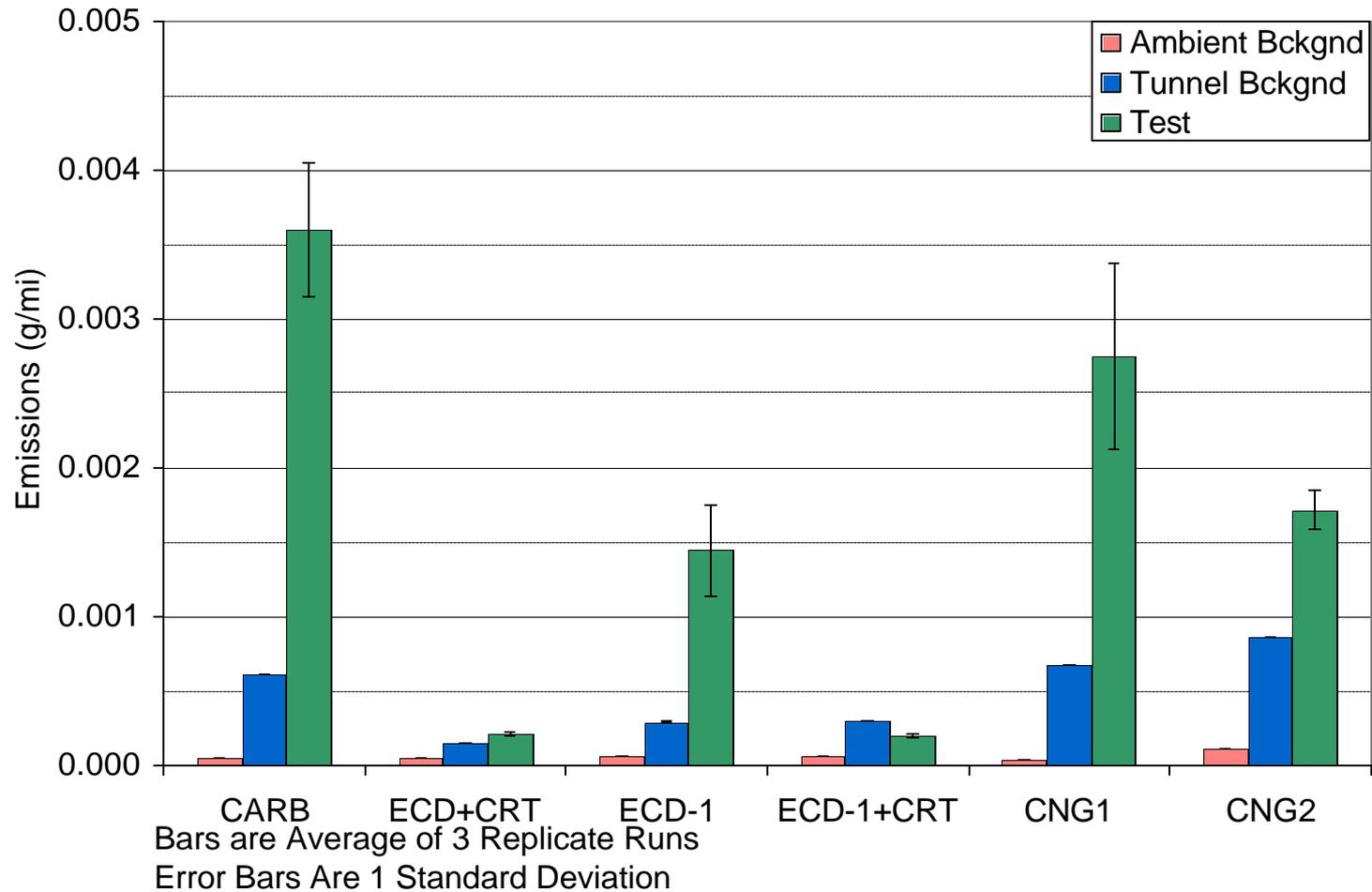


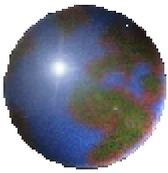
nMHCs by Compound Class



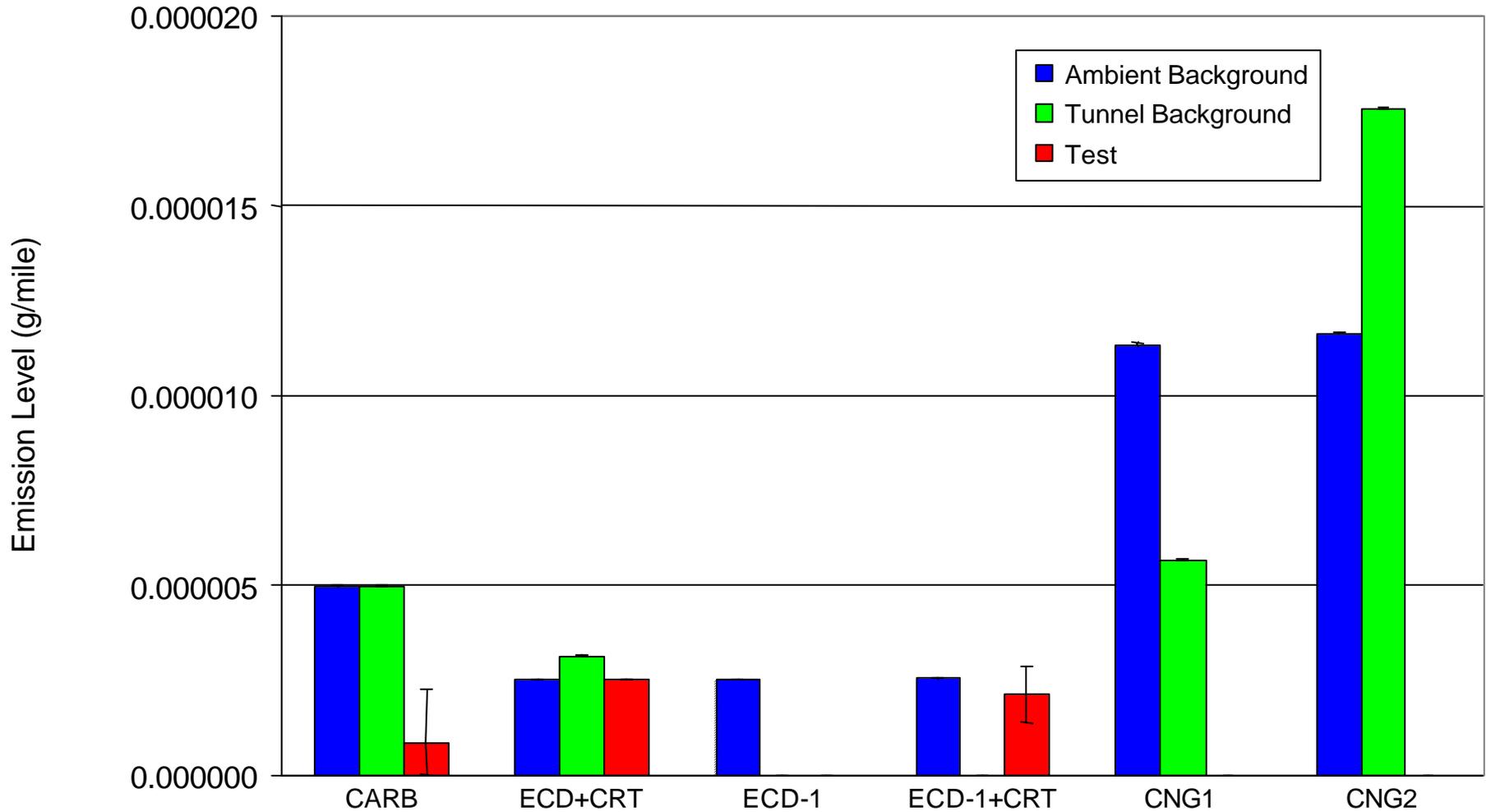


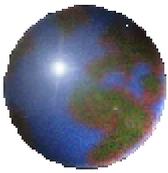
Speciation Data – Benzene





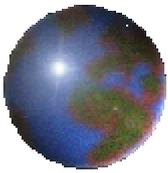
Speciation Data – 1,3 Butadiene



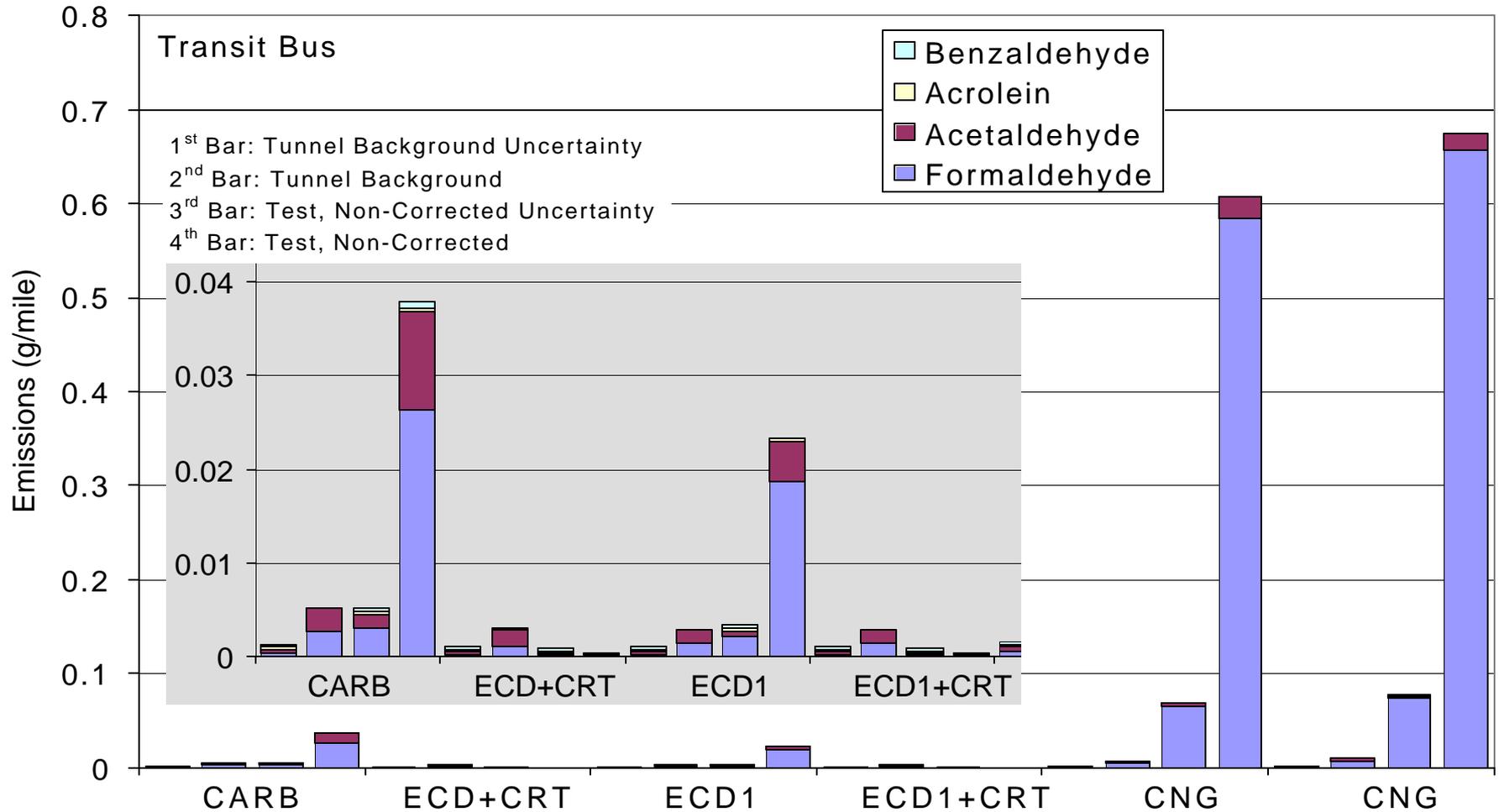


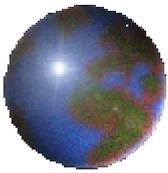
Speciation Data – 1,3 Butadiene

- ❖ Problems with detecting 1,3 Butadiene
 - ❖ Tunnel background levels varied between the morning and afternoon.
 - ❖ Difficult to separate from tunnel background levels.
 - ❖ Even though samples were analyzed within 2 hours of collection, possibility exists that there were still significant losses.
 - ❖ Samples in Tedlar bags can decay rapidly in the presence of diesel exhaust.
 - ❖ NO₂ and HNO₃ may reduce 1,3 Butadiene.

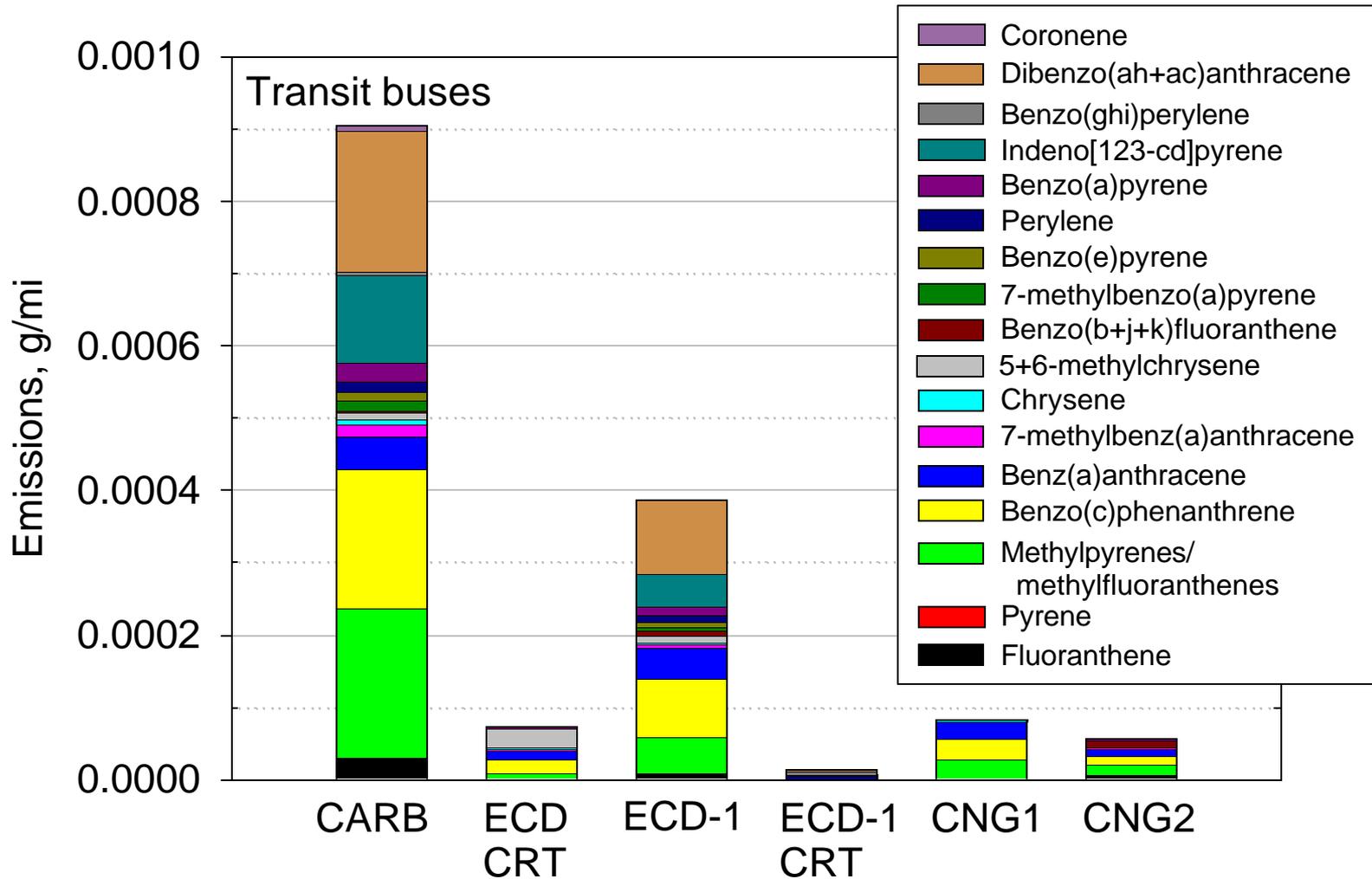


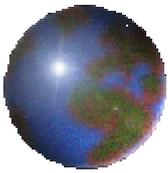
Speciation Data - Carbonyls



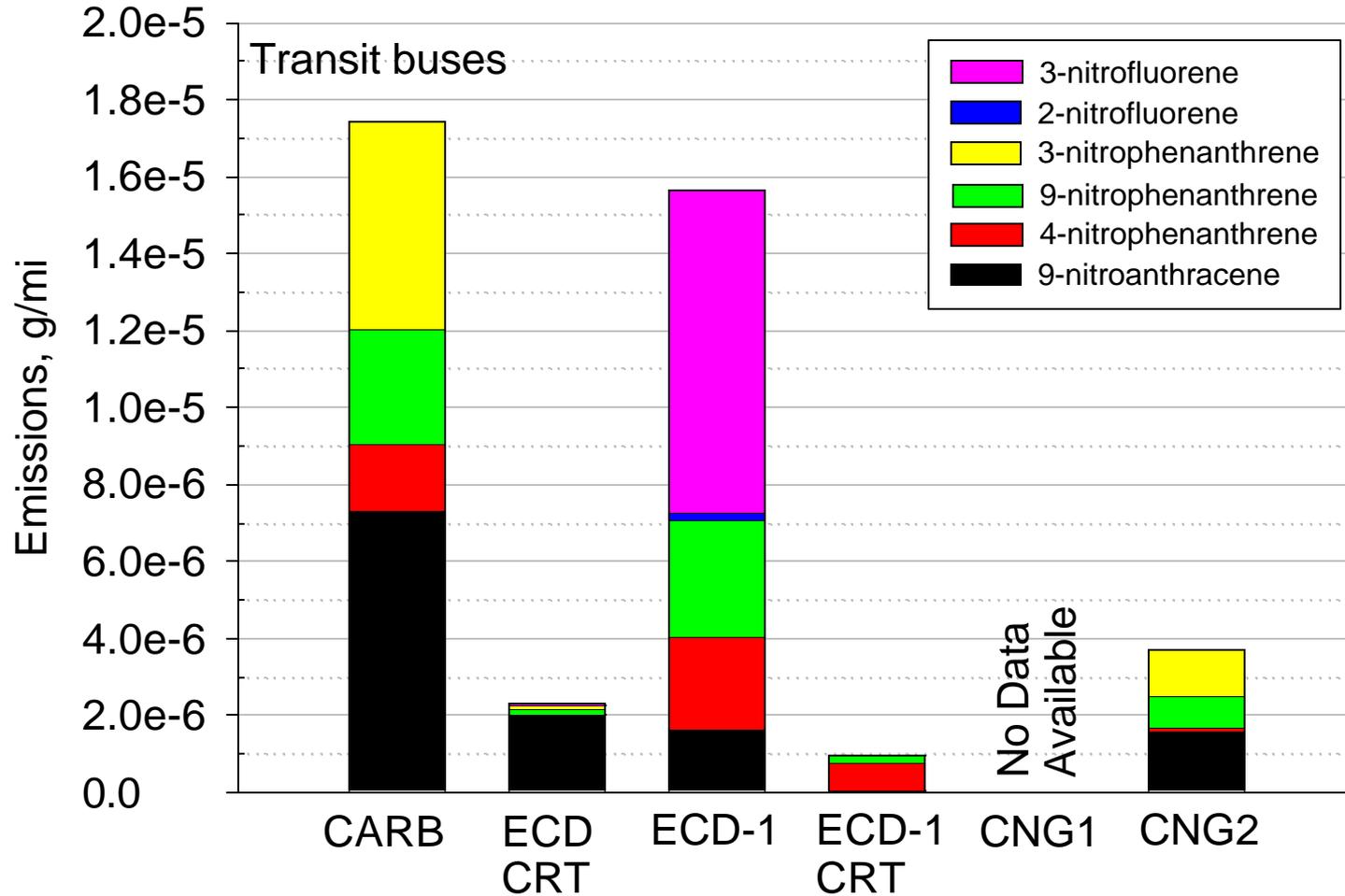


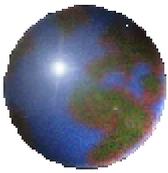
Speciation Data - 4+ Ring PAH





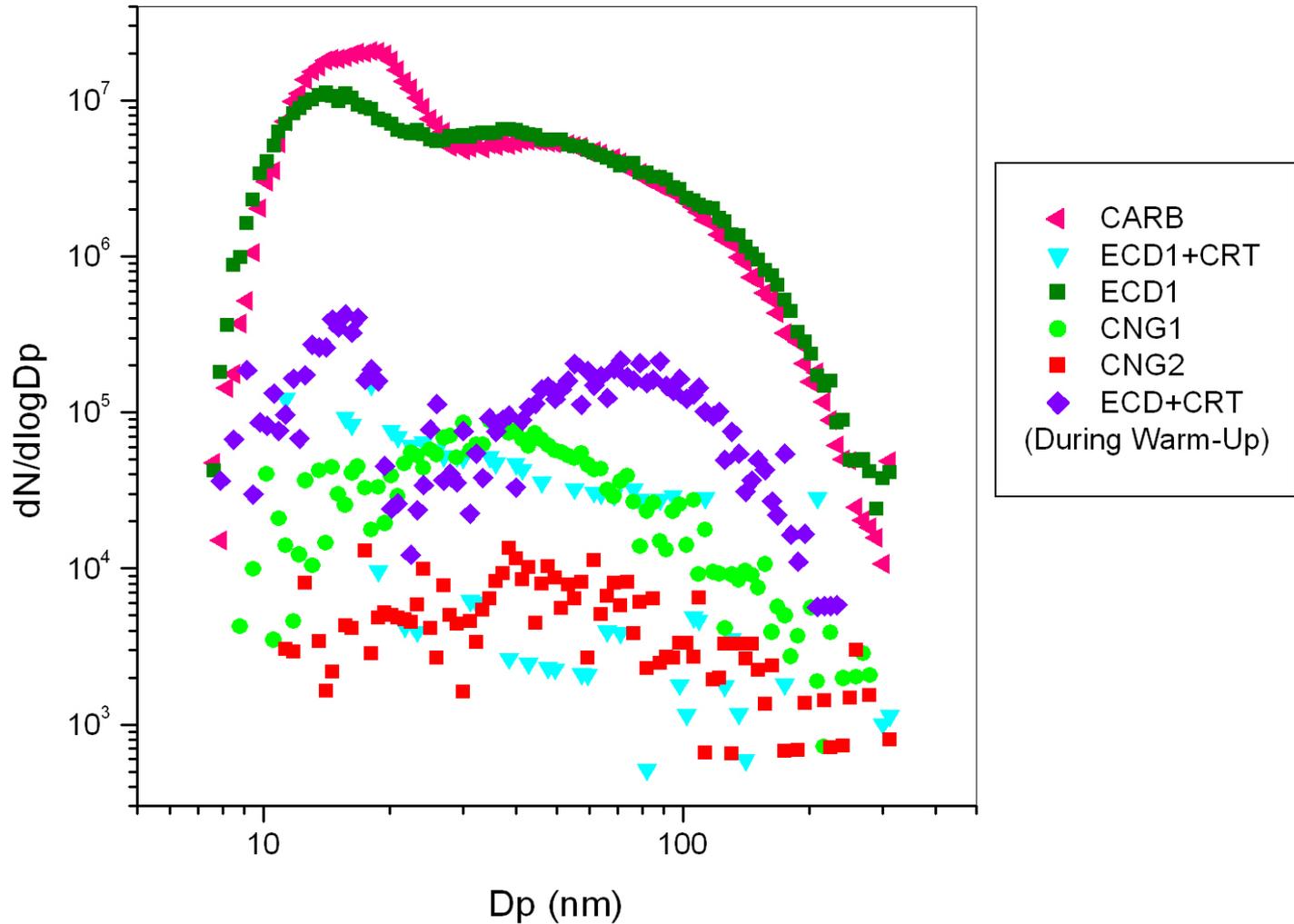
Speciation Data - 3 Ring Nitro PAH

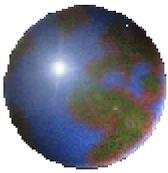




Particle Size

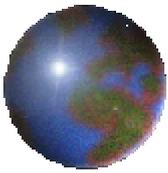
LA County MTA Transit Bus Diesel / CNG 1 / CNG 2
Steady-State 40 mph Operation





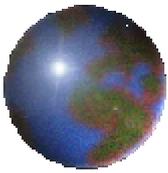
Speciation Data Summary

Emission Components	ULSD w/DPF	CNG
PM		=
NOx		>
THC/NMHC		<<
CO		<<
Benzene		<
Aldehydes		<<
1-3 Butadiene		?
PAH		~
nPAH		~
Particle Size		~



Conclusions

- ❖ ULSD w/ DPF shows proven reductions of air toxics and ozone precursors.
- ❖ Proven Durability
- ❖ Power, performance and reliability not impacted by fuel or filters
- ❖ Total Emissions are comparable to CNG Heavy Duty Vehicles
- ❖ Preliminary Toxic Score
 - ❑ Diesel w/ DPF < CNG
 - ❑ Awaiting mutagenicity results & CNG with after treatment



Conclusions, continued

- ❖ Need to look at the total emissions:
 - ❑ Total toxics
 - ❑ Ozone Impacts – Area specific
- ❖ Published SAE Papers
 - ❑ 2002-01-0432 & 2002-01-0433
 - ❑ 2002-01-2873 will be available in Oct, 2002
- ❖ Websites:
 - ❑ www.ecdiesel.com
 - ❑ www.ctts.nrel.gov/heavy_vehicle/what/ec_diesel.html