Effects of Natural Gas Fuel Composition on Vehicle Emissions

Clean Fuels Program Advisory Group Meeting

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Background

- AQMD, CARB and CEC co-funded CE-CERT to evaluate the effects of natural gas fuel composition on vehicle emissions, especially for heavy-duty vehicles
  - Assess the viability of natural gas blends with higher Wobbe numbers (Hot Gas)
  - Used for CARB's regulatory development to amend CNG fuel standards for motor vehicles

Project Scope

- Evaluate emissions and fuel economy for vehicles operating on various natural gas fuel compositions
  - Phase 1: 2 light-duty vehicles on 4 blends
  - Phase 2: 4 heavy-duty vehicles on 6-7 blends
- Comparison between test gases for criteria pollutants, fuel economy, PM number and size distribution, ammonia and carbonyl compounds
- $729K total project cost
  - CEC $400K, CARB $279K, AQMD $50K

Light Duty Vehicles Testing

- Test Vehicles
  - 2006 Honda Civic GX, SULEV
  - 2002 Ford Crown Victoria, ULEV
- Test Fuels

Gas #	Description	methane	ethane	propane	I-butane	N_2	MN	Wobbe #	HHV	H/C
1	Baseline, Pipeline gas	96.05	1.79	0.37	0.17	1.62	97	1345	1021	3.94
2	CARB certification gas	90.20	4.04	2.03		3.73	86	1329	1038	3.84
3	Hi Wobbe	83.92	9.43	3.79	1.86	1.00	68	1438	1177	3.63
4	Modified gas 3	84.03	6.86	3.76	1.85	3.50	68	1385	1131	3.66

- FTP and Unified Cycle
- Testing at CE-CERT's Vehicle Emissions Research Lab

Test Results
Light Duty Vehicles

- Clear trend for fuel economy, CO_2 and NMHC for richer gases with higher WN (CNG #3 & 4)
  - Better fuel economy
  - Higher CO_2 emissions (Honda)
  - Very low NMHC levels, but levels increased for richer gases
- No clear trend for THC, CO and NOx
  - THC showed higher emissions for higher MN (CNG #1 & 2) for Crown Victoria, but no trends for Honda
  - CO emissions higher for CNG #3 & 4 for Honda under some test conditions, but no effects for Crown Victoria
  - Only limited fuel effects for NOx for both vehicles

Heavy Duty Vehicles Testing

- Test Vehicles

#	Type	Engine	Control
1	Transit Bus	2009 Cummins 8.9L ISL-G (stoichiometric)	TWC and EGR
2	Transit Bus	2004 JD 8.1L 6081H* (lean burn)	OC
3	Transit Bus	2003 Cummins 8.3L C-Gas Plus (lean burn)	OC
4	Refuse Truck	2002 Cummins 8.3L C-Gas Plus (lean burn)	OC

*JD bus was tested twice due to a mechanical malfunction

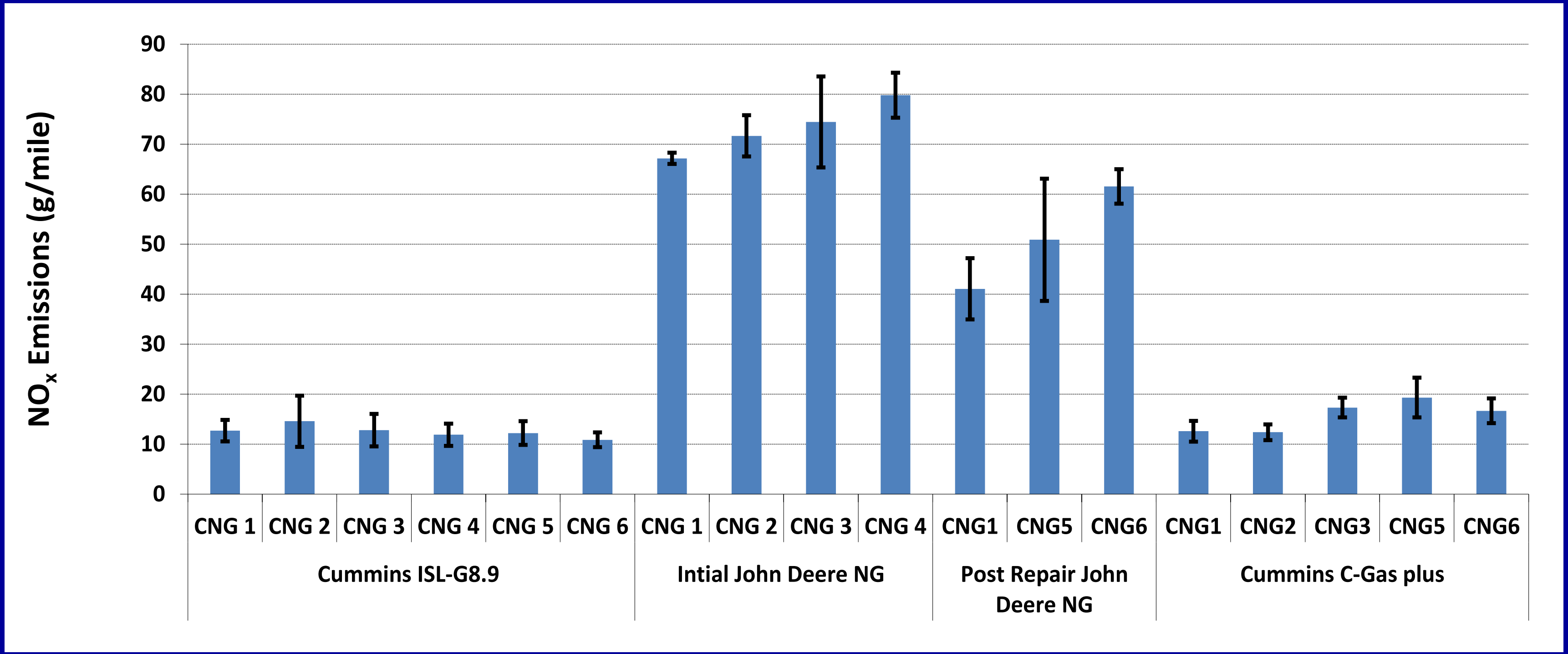
- Test Cycles
  - Buses: Central Business District
  - Refuse Truck: William H. Martin
- Testing at CE-CERT’s Heavy Duty Chassis Dynamometer Facility

Heavy Duty Vehicles Test Fuels

Gas #	Description	methane	ethane	propane	MN	WN	HHV	H/C ratio
1	Baseline, Texas Pipeline	96	1.8	0.4	99	1339	1021	3.94
2	Baseline, Rocky Mtn Pipeline	94.5	3.5	0.6	95	1361	1046	3.89
3	Peruvian LNG	88.3	10.5	0	84	1385	1083	3.81
4	Middle East LNG	89.3	6.8	2.6	80	1428	1136	3.73
5	High Ethane	83.65	10.75	2.7	75.3	1385	1115	3.71
6	High Propane	87.2	4.5	4.4	75.1	1385	1116	3.70
7	L-CNG*	98.4	1.2	0.3	103.1	1370	1029	3.96

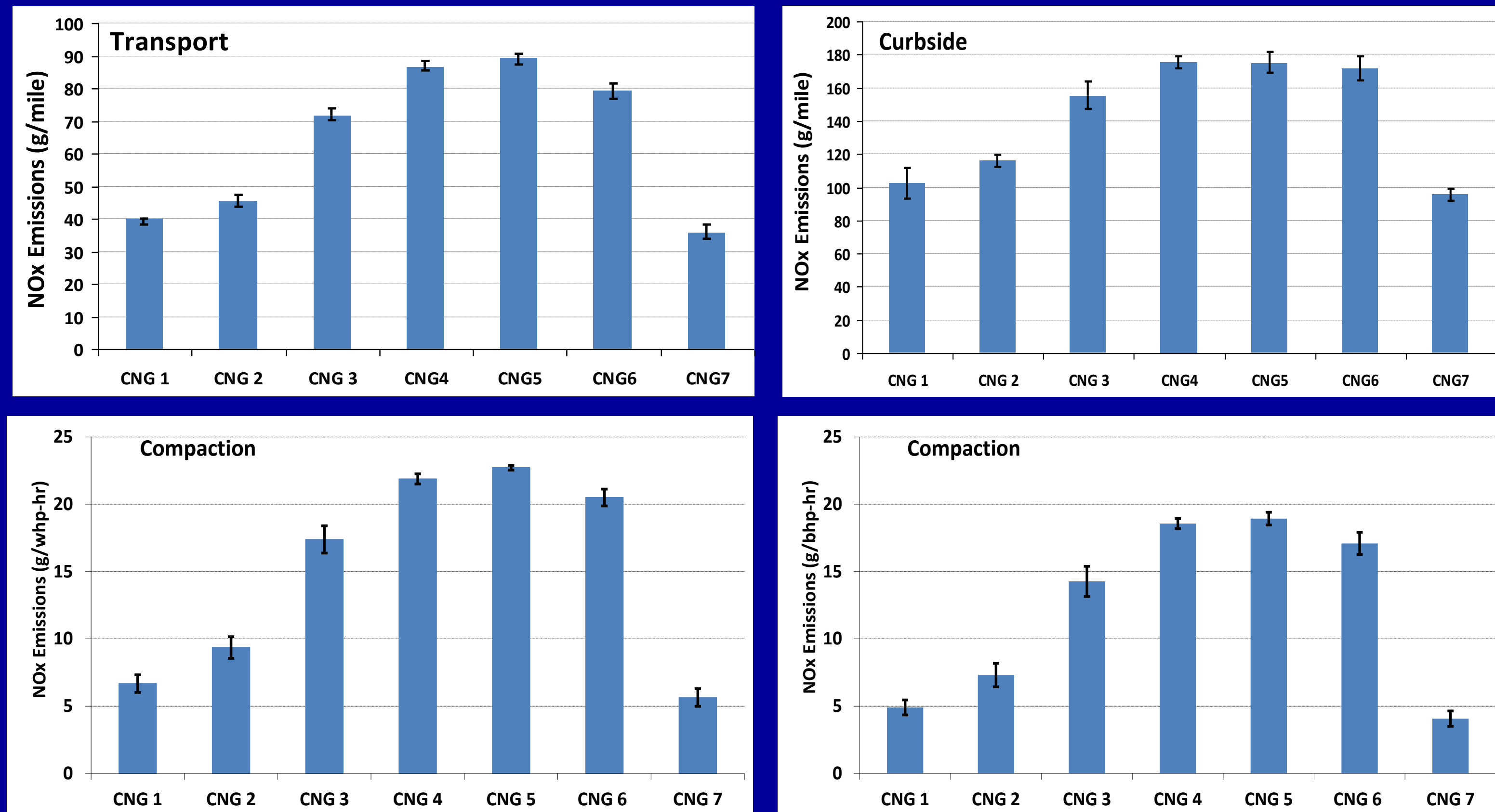
*L-CNG is tested only with the refuse collection truck

Heavy Duty Test – NOx (Buses)



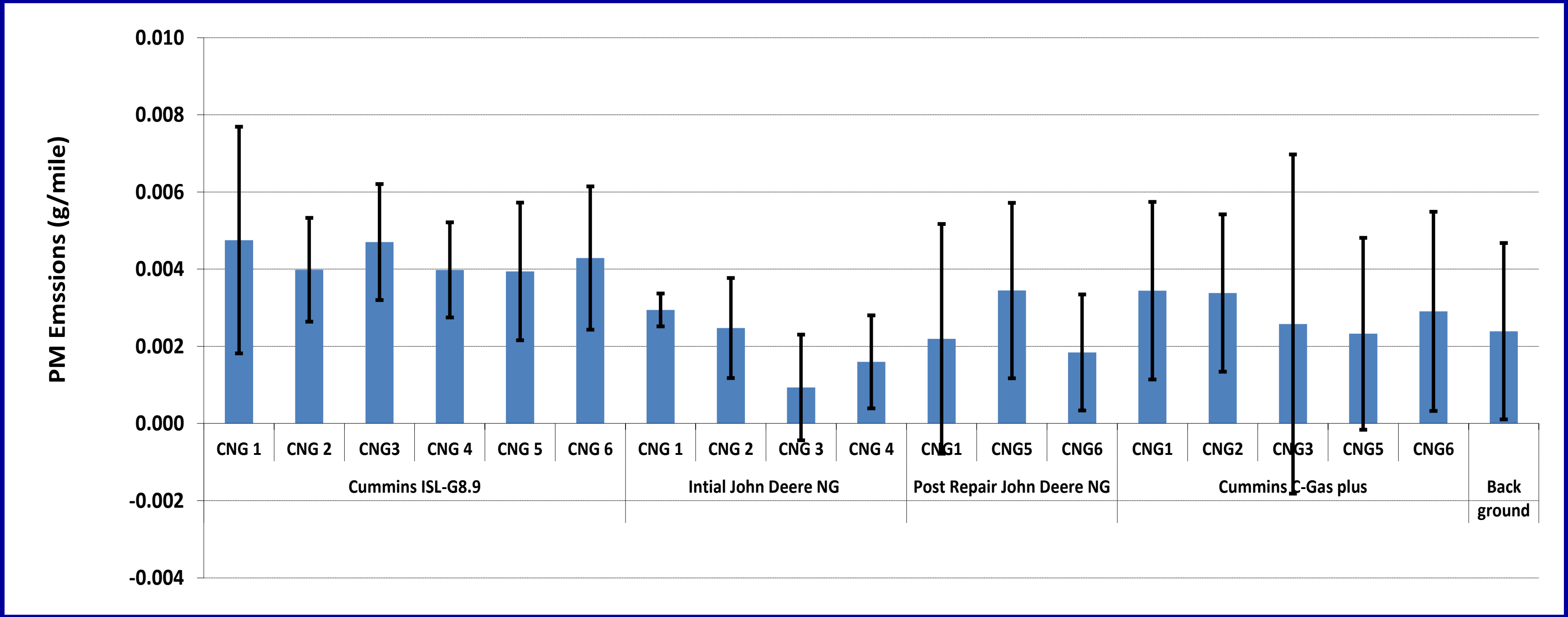
- NO_x emission levels for the Cummins ISL-G bus and C-Gas Plus bus were significantly lower than those of the JD bus.
- For JD and C-Gas Plus buses, higher NO_x emissions for the richer gases containing higher levels of heavier hydrocarbons but no significant trend for the ISL-G bus

Heavy Duty Test – NOx (Refuse Truck)



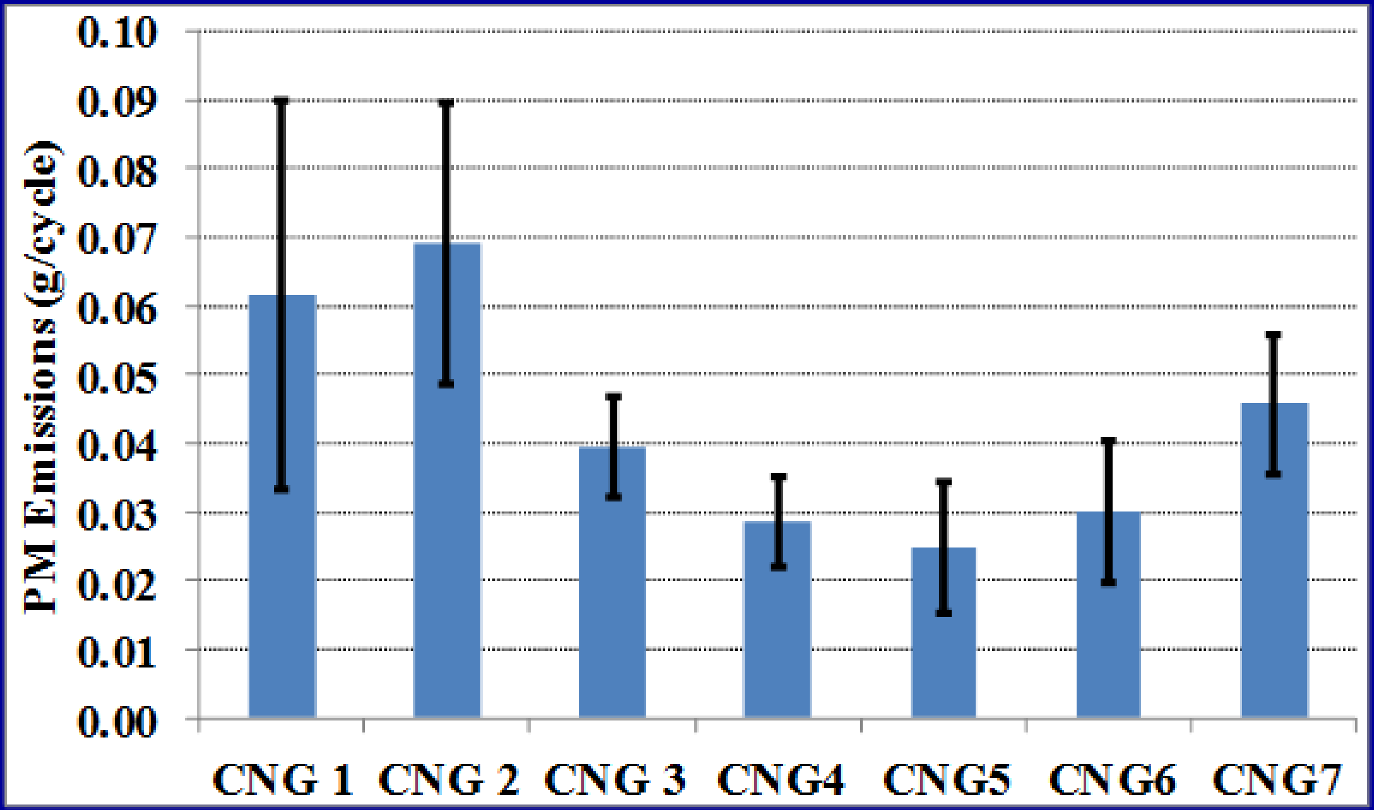
- Refuse truck showed the strongest fuel effects compared to the three buses, especially for the compaction segment with NOx increase of 286% over CNG 1.

Heavy Duty Test – PM (Buses)



- Total PM mass emissions were low for all three buses on an absolute level, and are at the same levels as the tunnel background.
- For the post-repair JD bus, the Cummins ISL-G bus, and the Cummins C-gas Plus bus, there were essentially no differences between PM mass for different fuel blends.

Heavy Duty Test – PM (Refuse Truck)



- Richer gases with more higher hydrocarbons showing lower PM levels, while the gases with higher MN showed higher PM levels.

Test Results Summary
Heavy Duty Vehicles

- Lean burn engine vehicles showed clear trends for some emissions
  - Higher fuel economy, NOx and NMHC for richer gases (CNG #3,4,5 & 6)
    - NOx increase as much as 286% for refuse truck (compaction)
  - Higher THC, CH4 and formaldehyde for lower WN gases (CNG #1,2, & 7)
  - Higher PM for lower WN (refuse truck)
    - PM emissions very low, close to background level for buses
- Cummins ISL-G bus showed no fuel effects except for fuel economy, and had the lowest emissions except CO & NH_3
- Refuse truck showed the strongest fuel effects
- No strong fuel effects for CO and CO_2

Proposed Testing Project

- Retest John Deere bus
  - Redo testing of gases that were only tested during the initial testing (CNG #1,2 and 3)
- Testing of an ISL-G refuse truck or drayage truck
  - Determine if fuel effects are not significant for different cycles for ISL-G engines
- 195K total project cost estimate
  - $120K from CARB, requesting $75K from AQMD