



**New York City Transit
Department of Buses**

Comparison of Clean Diesel Buses to CNG Buses

DEER Conference 2003

Newport, RI

August 26, 2003

Outline

- Background
- Regulated Emissions
- Unregulated Emissions
 - Toxicity
 - Particle Size
- Economic Analysis
 - Cost Factors
 - Capital Costs
 - Operating Cost
 - NPV of Life Cycle Costs
- Issues For Future

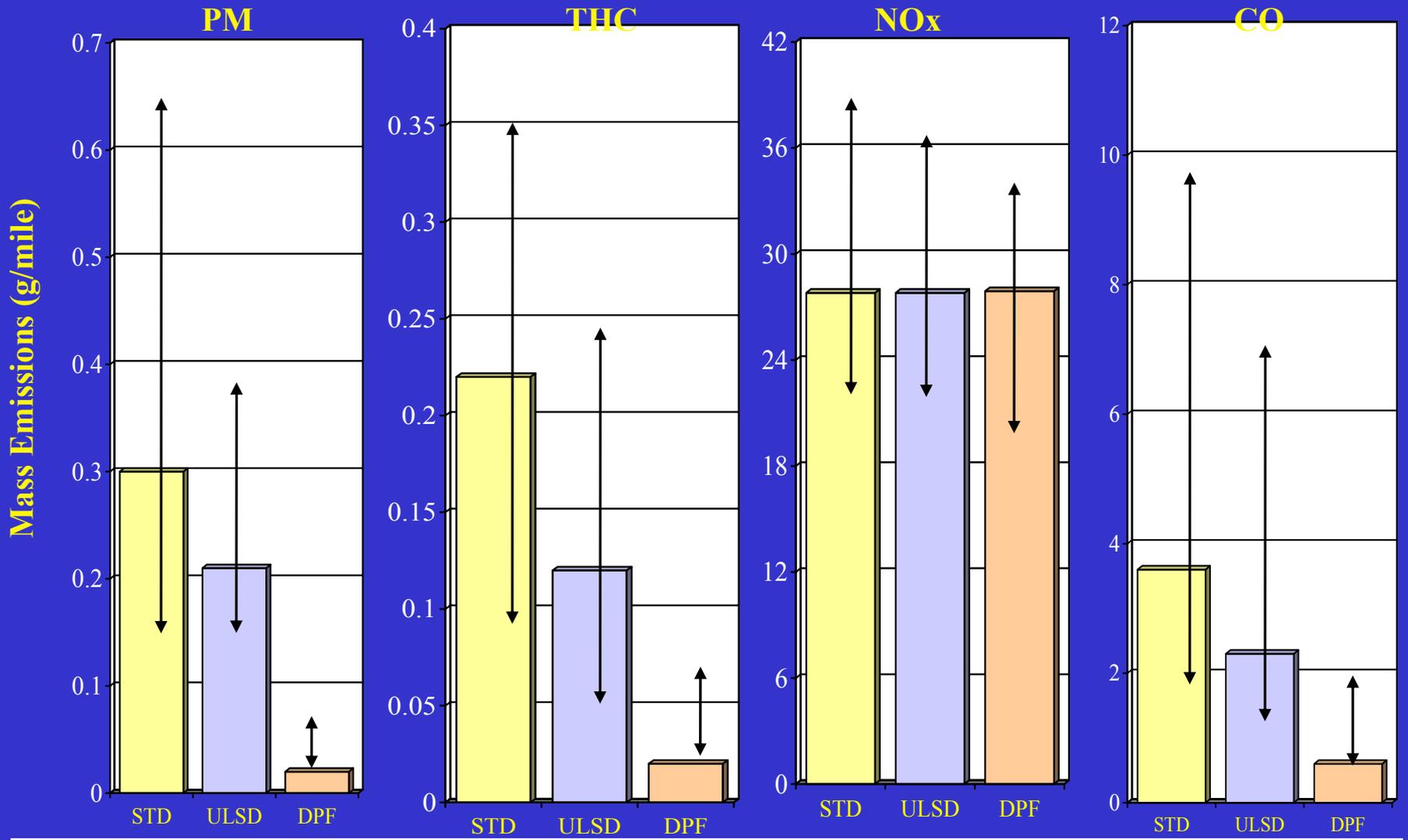
Technologies Compared

- “Baseline Diesel”
 - Model years 1998 – 2001
 - Diesel Oxidation catalyst (DOC) installed
 - “Standard” on-road diesel fuel (typical 350 PPM sulfur)
 - NOT including EGR or other post 10-02 technologies
- Natural Gas Buses
 - Model years 1998 – 2001
 - Mostly CNG; a few LNG
 - No oxidation catalyst installed
- “Clean Diesel”
 - Model years 1998 – 2001
 - Ultra low sulfur Diesel fuel (<30 PPM sulfur)
 - Diesel Particulate Filter (DPF) installed
 - NOT including EGR or other post 10-02 technologies

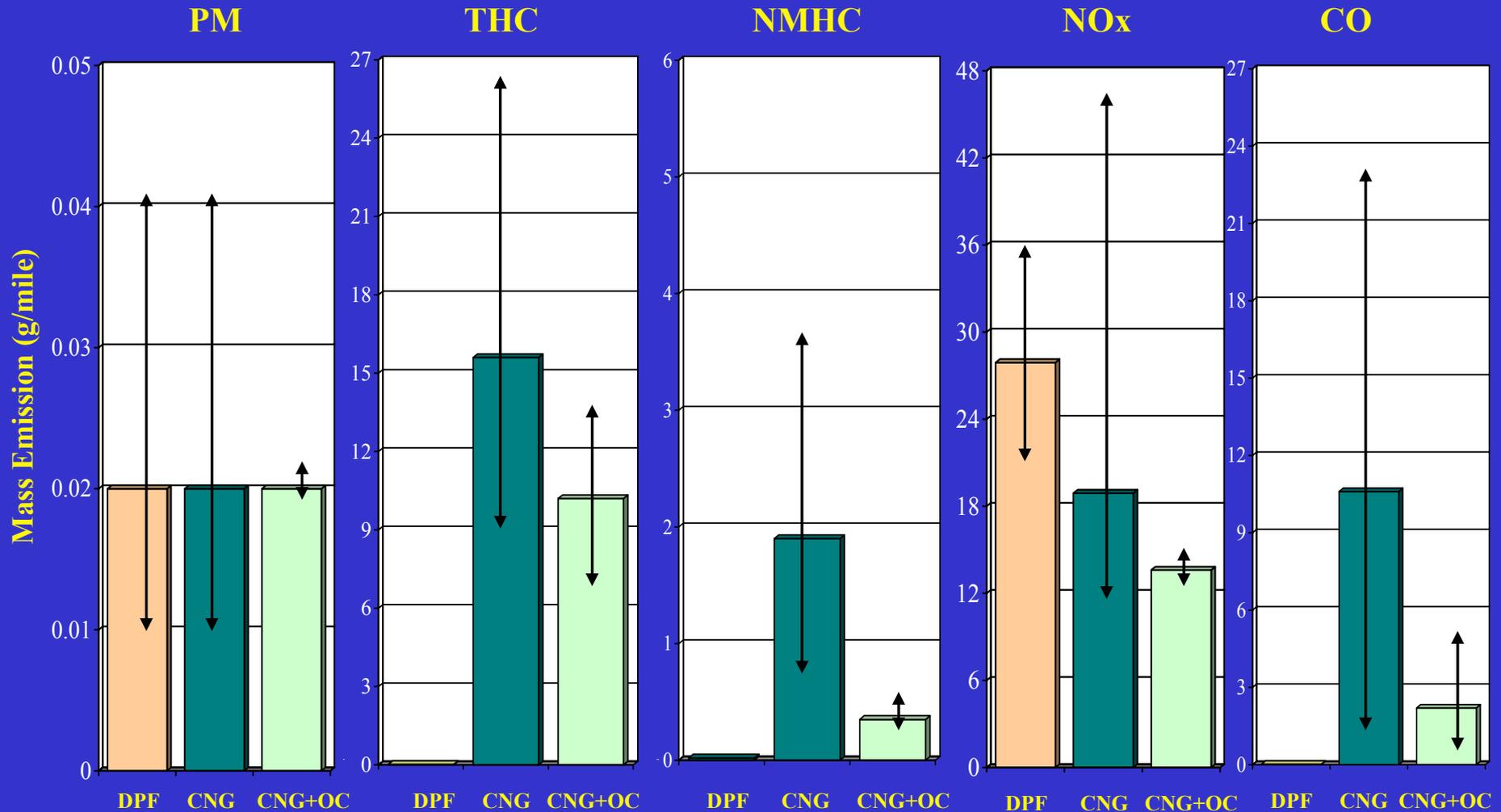
Data Sources

- Emissions
 - NY Clean Diesel Demonstration Program
 - California EC-Diesel Technology Validation Program
 - Miscellaneous published sources (WVU, CARB)
- Economic Analysis
 - NYCT data from operating CNG buses since 1995 and Clean Diesel Buses since 2001
 - Published information on CNG costs from LACMTA, GCRTA, and Coast Mountain Bus

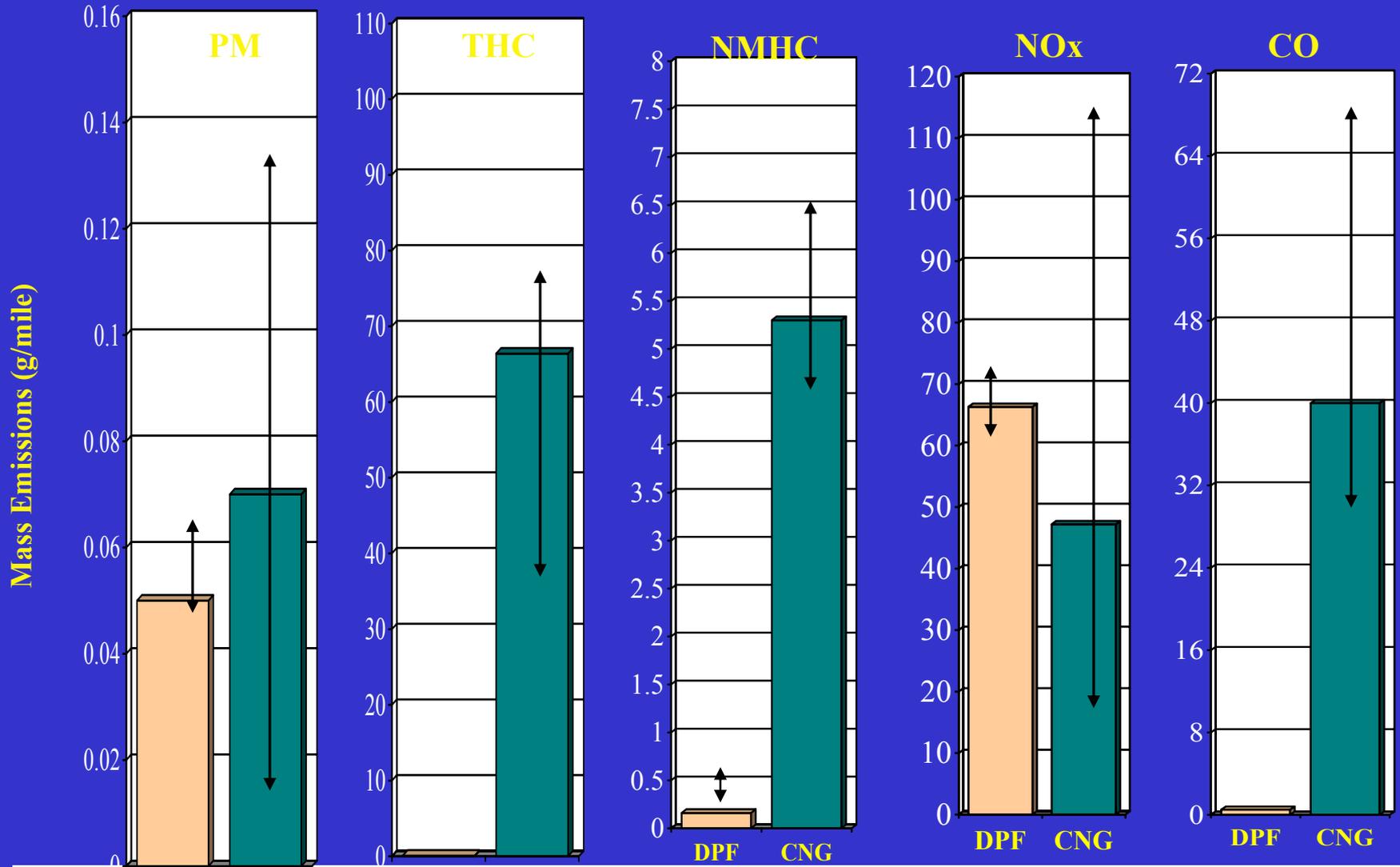
Effect of Clean Diesel on Regulated Emissions (CBD Cycle)



Regulated Emissions of Clean Diesel vs CNG (CBD Cycle)

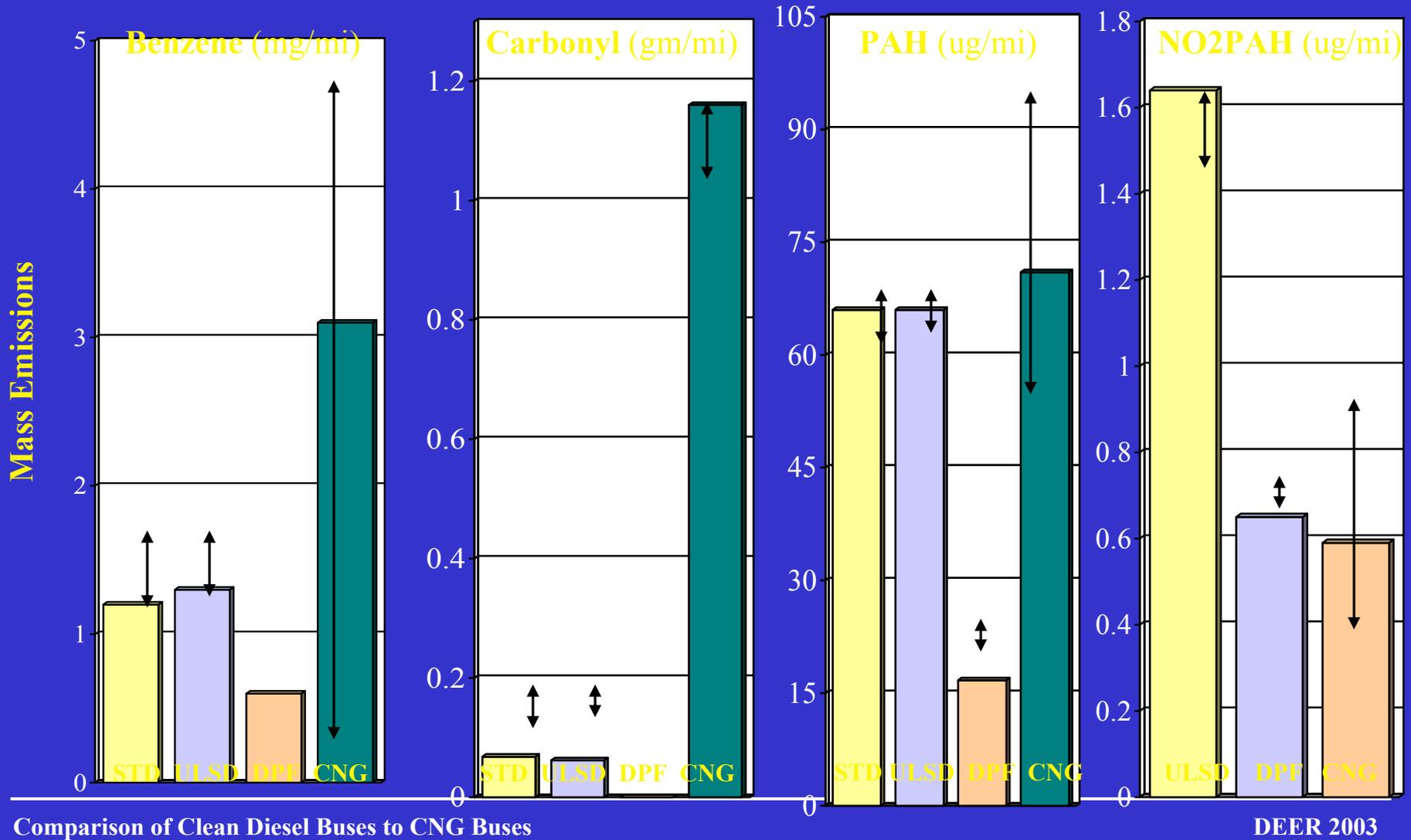


Regulated Emissions of Clean Diesel vs CNG (NYB Cycle)



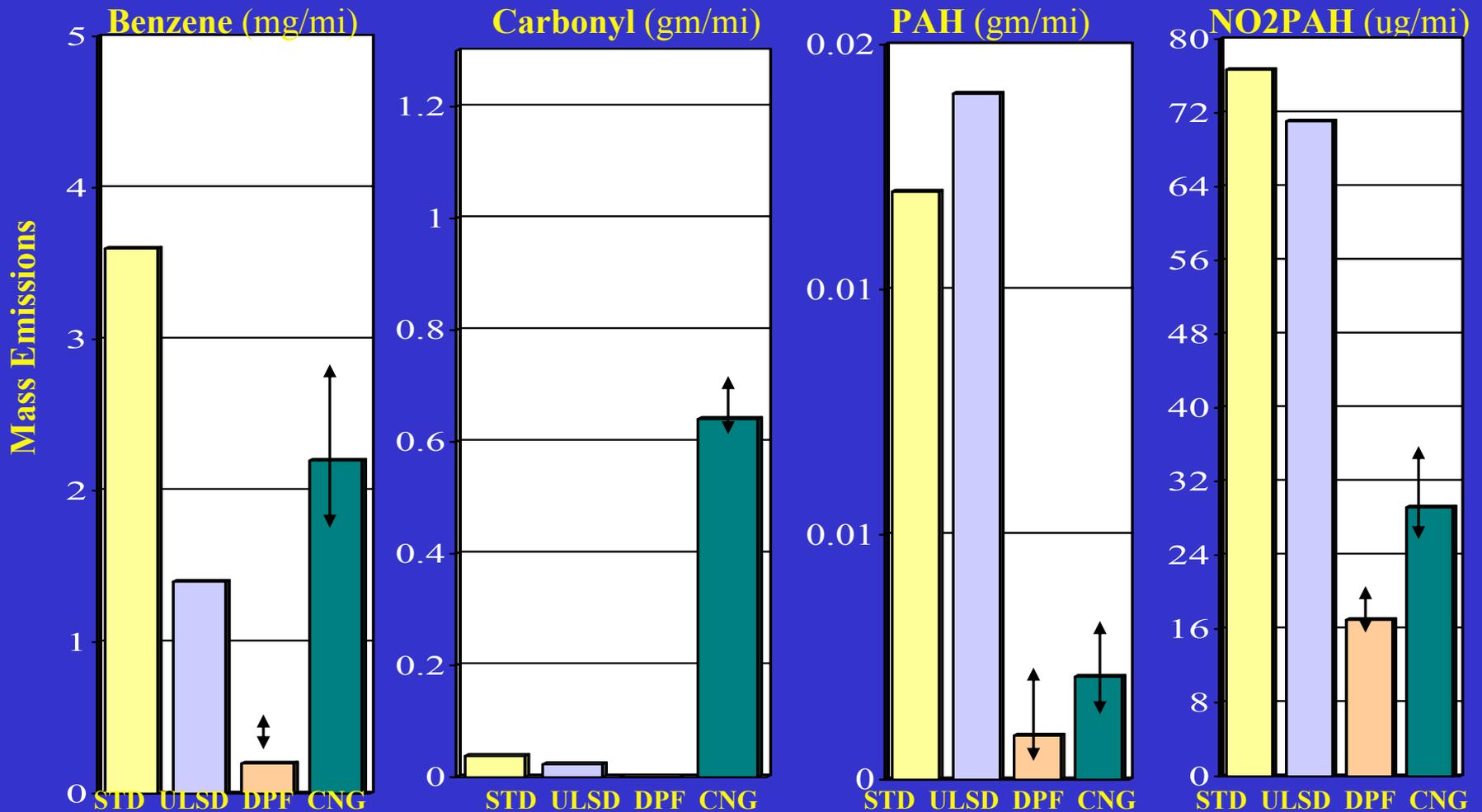
Unregulated Emissions of Clean Diesel vs CNG

Data from New York Clean Diesel Demonstration Program, CBD Cycle

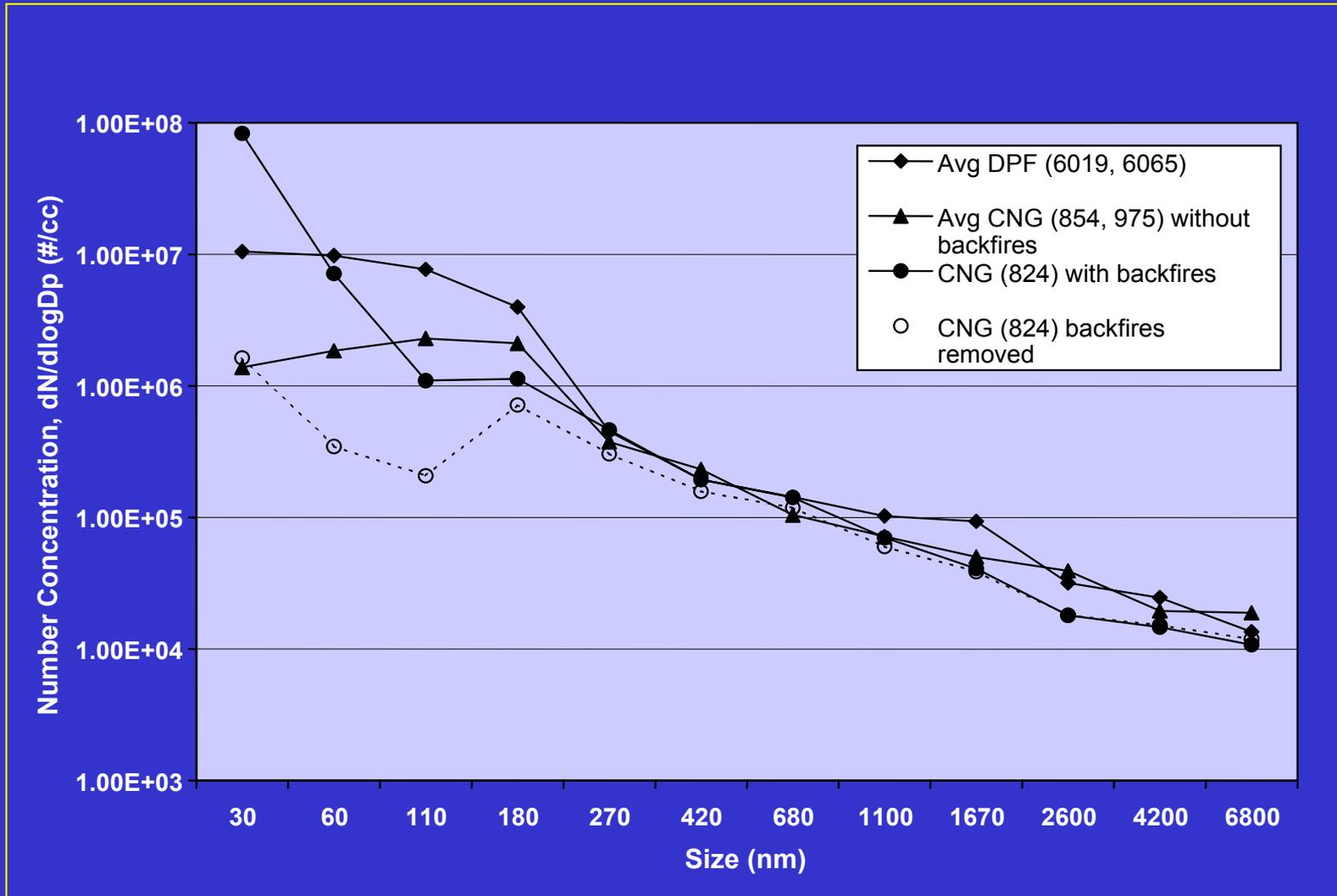


Unregulated Emissions of Clean Diesel vs CNG

Data from California EC Diesel Technology Validation Program, CBD Cycle



PM Particle Count by Size



Emissions Summary

**CNG “Better”
than Clean Diesel**

NO_x

**Clean Diesel
“Better” than
CNG**

THC

NMHC

CO

Benzene

Carbonyl

PAH

**CNG & Clean
Diesel Equal**

PM mass

**PM particle
number and size**

NO₂PAH

CNG Cost Factors

Compared to STANDARD diesel buses, CNG buses cost more for:

Capital

Bus purchase

- Engines, CNG tanks & piping

Fuel station installation

- High pressure compressors

Depot safety modifications

- Increased ventilation
- Methane detection
- remove/mitigate emission sources

Operating

NG fuel (+ \$0.11/mile)

- Cost of compression
- Lower fuel economy

Bus maintenance (+ \$0.20/mile)

- Engine, fuel system
- Lower reliability

Fuel station maintenance

- Heavy duty engines & compressors

Clean Diesel Cost Factors

Compared to STD diesel buses, Clean Diesel buses cost more for:

Capital

DPF purchase & installation

- Including spares for cleaning

Diesel fuel station installation

- Included only for “apples to apples” comparison – no actual investment required to switch from standard diesel to ULSD

Operating

ULSD fuel (+ \$0.04/mile)

- Mostly based on increased logistics cost for non-commercial fuel

Annual Cleaning

Cleaning/replacement of “plugged” units

- Result of engine upset conditions (5-7.5%/year)

Capital Cost Comparison

- ✓ Incremental costs compared to “standard” diesel for purchasing 200 buses and outfitting one depot

Cost Element	CNG		Clean Diesel	
	Per Bus	Total	Per Bus	Total
Incremental Bus Cost	\$30,000	\$6 million		
CNG Fuel Station	NA	\$5 million		
Depot Modification	NA	\$20 million		
DPF (incl spares)			\$5,900	\$1.2 million
Diesel Fuel Station			NA	\$0.5 million
TOTAL		\$31 million		\$1.7 million

Operating Cost Comparison

- ✓ Incremental annual costs compared to “standard” diesel for operating 200 buses at one depot

Cost Element	CNG		Clean Diesel	
	Per Bus	Total	Per Bus	Total
Incremental CNG Fuel	\$2,860	\$0.6 million		
CNG Fuel Station Maintenance	NA	\$0.9 million		
Incr Bus Maintenance	\$5,200	\$1.0 million		
Incremental ULSD			\$1,040	\$208,000
Diesel Fuel Station Maintenance			NA	\$92,000
DPF replacements			\$137	\$27,400
Annual DPF Cleaning			\$670	\$134,000
TOTAL		\$2.5 million		\$461,400

NPV Life-Cycle Analysis

- Discount rate 6%
- Period of analysis – 30 years
- Based on operating 200 buses at one depot location
- Investments based on life cycle of equipment:



Life Cycle Cost Comparison

- ✓ Incremental costs compared to “standard” diesel for operating 200 buses at one depot location
- ✓ Does not include overhaul of CNG and diesel engines at mid-life (assumed equivalent)

	CNG	Clean Diesel
NPV of Capital Costs	\$33,653,806	\$3,448,862
NPV of Operating Costs	<u>\$36,651,891</u>	<u>\$6,732,158</u>
NPV of TOTAL COSTS	\$70,305,697	\$10,181,020
Annualized NPV of Total Costs	\$2,343,523	\$339,367

Summary

- In comparison to CNG, diesel is inherently more fuel efficient
- While CNG has historically had an inherent emissions advantage, new technologies applied to diesel have dramatically closed the gap
- Even with the new technologies (which have added cost), diesel retains a significant cost advantage over CNG

Issues

- Chassis testing shows CNG NOx is much more variable than diesel NOx – implications for “real world” emissions?
- Effect of catalyst on CNG emissions – more data needed
- EGR and other technologies certified to reduce diesel NOx post Oct 2002 – chassis test data required to judge “real world” effects
- Effect of 2007 EPA NOx regulations
 - will NG retain any inherent NOx advantage?
 - Will diesel retain current cost advantage?
- Measurement of unregulated “toxic” emissions – standards required for collection and analysis