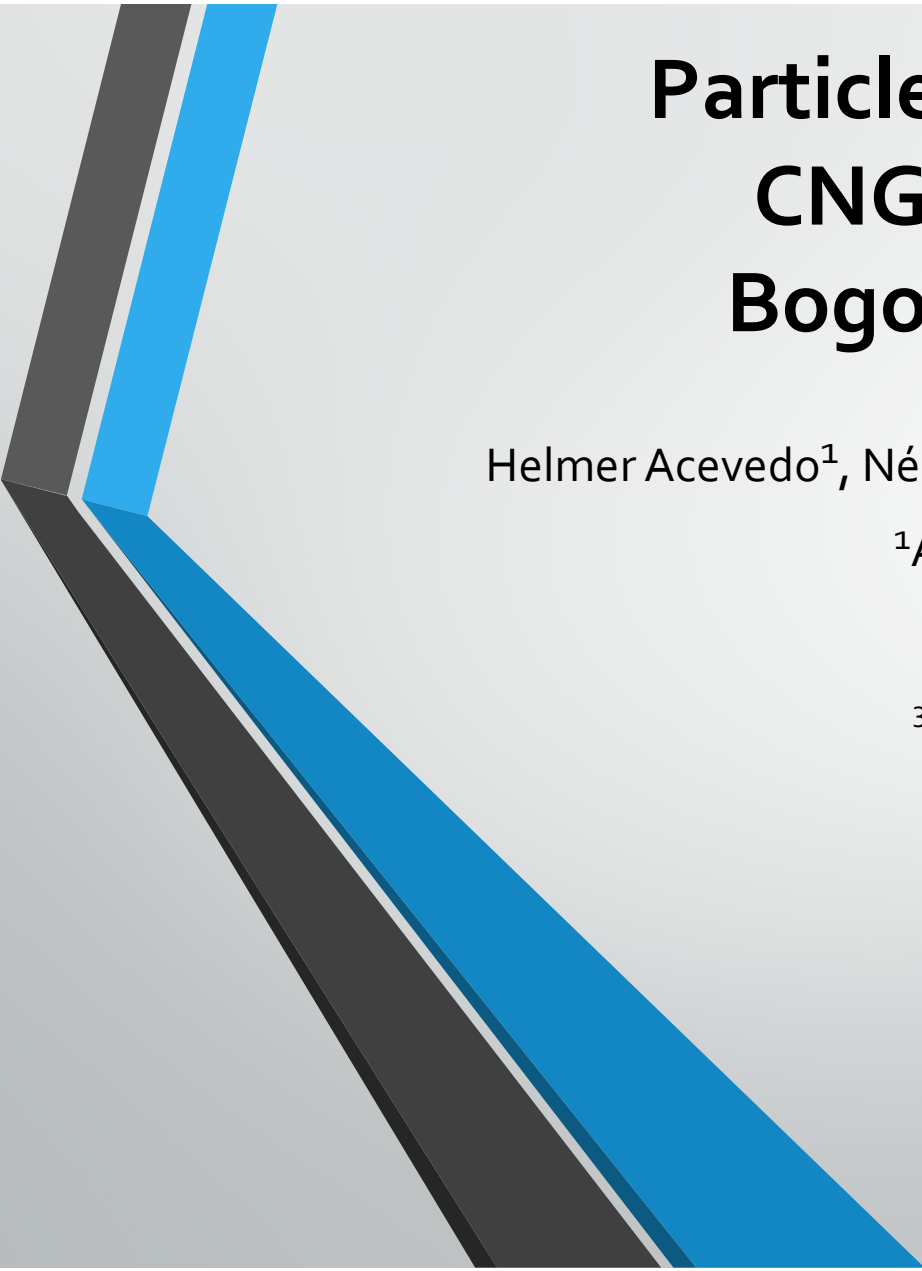




Particle Number Measurements of a CNG Euro VI Bus Operating in the Bogota's Public Transport System

Helmer Acevedo¹, Néstor Rojas², Edwin López³, Felipe Rodriguez³, Luis Cachón⁴.

¹Associate Professor – Mechanical Engineering Department

²Associate Professor – Chemical Engineering Department

³Graduate Students – Mechanical Engineering Department

⁴Matter Aerosol AG

Engineering Faculty – Universidad Nacional de Colombia

Carrera 30 # 45-03, Edificio 453 Oficina 401

Tel.: 571-3165320. Fax.: 571-3165333

Email: hacevedog@unal.edu.co



Content

1. Introduction
2. Bus Specifications
3. Experimental Setup
4. Results
5. Conclusions
6. Acknowledgments
7. Questions

1. Introduction

- Bogota D.C. is the Capital of Colombia
- Bogota's Population is 8 Million Inhabitants
- Bogota D.C. is located at 2650 masl.
- Bogota D.C. is the third largest city in Latin America.

BOGOTA's OBJECTIVES AND GOALS

- ✓ *Reduce PM_{10} by 10% and implementing the equipment for monitoring $PM_{2.5}$ in the city*
- ✓ *Reduce CO, NO_x, THC and PM of public transport by 10%.*
- ✓ *Reduce the causes of cardio-respiratory diseases*

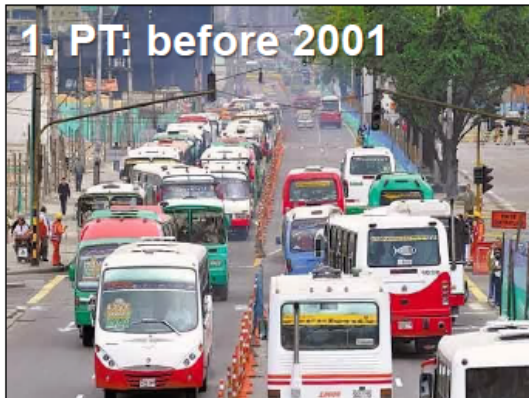
10 Year Plan of Air Quality Improvement in Bogota

Air Quality Monitoring

Control to Mobil and Industrial Sources of emissions and Control to Automotive Diagnostics Centers

Design an Early Warning System

1. Introduction



Fuel: More than 1.200 ppm [S]



Fuel: Less than 50 ppm [S] since 2010

3. SITP (Starting 2012 - 2014)



ALCALDÍA MAYOR
DE BOGOTÁ D.C.

SECRETARÍA DISTRITAL DE AMBIENTE

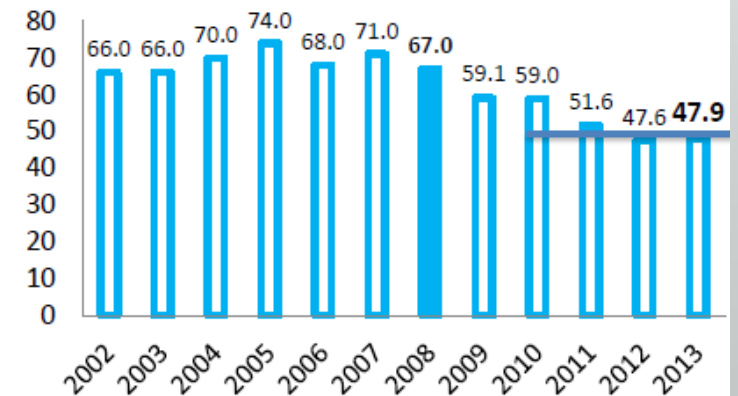
BOGOTÁ
HUMANANA

Source: Transmilenio - 2013

Stage of the Public Transport		Vehicles/Year			
		2008	2012	2013	2014
SITP	Stage I	1.070	2.213	5.565	12.416
	Stage II				
	Stage III				
	Zonal				
Traditional public transport		16.168	15.389	11.160	0
TOTAL		17.238	17.602	16.725	12.416

Source: Compile SDA, 2014 by information from Transmilenio S.A, 2013

Annual average PM₁₀ level (µg/m³)



Source: SDA, 2014

1. Introduction

Objective:

The objective of this work was to obtain the fuel efficiency and the emission factors of a CNG Euro 6 bus running under local conditions and compare them to diesel engine technology.

2. BUS SPECIFICATIONS



SCANIA K340 – Compressed Natural Gas (CNG)
Engine Reference: OC09 102/250 kW (340 HP) -
Stoichiometric

G.V.W.	kg	24600
Curb Weight	kg	15600
Gross Axle 1 Weight	kg	7100
Gross Axle 2 Weight	kg	11500
Gross Axle 3 Weight	kg	6000

Displacement Volume	9.3 L
Cylinders	5
Emission Standard	Euro 6
Max Torque. (1100-1400 rpm)	1600 Nm
Max Power. (at 1900 rpm)	250 kW
Exhaust Aftertreatment System	3-Way Catalytic Converter

Transmission Reference	ZF 6 AP 1400 B (Ecolife)
Type	Automatic
Retarder	ZF - Automatic

3. EXPERIMENTAL SETUP

TWO TYPES OF TEST WERE CARRIED OUT:

1. ON-BOARD TESTING (AT G.V.W.)
2. CHASSIS DYNAMOMETER TESTING

TWO PARAMETERS WERE OBTAINED:

1. FUEL EFFICIENCY
2. EMISSION FACTORS

3. EXPERIMENTAL SETUP (ON-BOARD TESTING)



Dekati Elpi Plus and FPS4000.
Real time number size
distribution and concentration
measurement.
6 nm – 10 μm , 14 size fractions



NanoMet3

Portable solid particle counter provides a complete data string with following values:

- particle number concentration ($\#/\text{cm}^3$)
- average size (nm), 10...700 nm (within mode diameter of 10...300 nm)
- calculated particle mass (mg/m^3)
- LDSA—Lung Deposition Surface Area ($\mu\text{m}^2/\text{cm}^3$)



SEMTECH-G: gas emissions testing monitor measures emissions of CO, CO₂, total Hydrocarbons (THC), NO, and NO₂. The Semtech-G unit uses infrared absorption technology to measure CO and CO₂, ultraviolet absorption technology to measure NO and NO₂, and a flame ionization detector to measure total hydrocarbon emissions. The Semtech-G is also equipped with a GPS device to measure location and speed and it has been approved by US-EPA



3. EXPERIMENTAL SETUP (ON-BOARD TESTING-ROUTE)

Source:
Google Earth®



Length of the route: 73.9 km

Maximum Slope: 16%.

First Zone: Heavy Traffic (Average Speed: 12 km/h)

Second Zone: Up and Down.

Third Zone: Moderate Traffic (Average Speed: 20 km/h)

Fourth Zone: Highway (Average Speed: 30 km/h)

The bus stops at all bus stops for 2 minutes.

There are 62 bus stops.

Data Collected: Total Distance: 798 km, Total Time: 42:15
[hh:mm]

3. EXPERIMENTAL SETUP (DYNO TESTING)

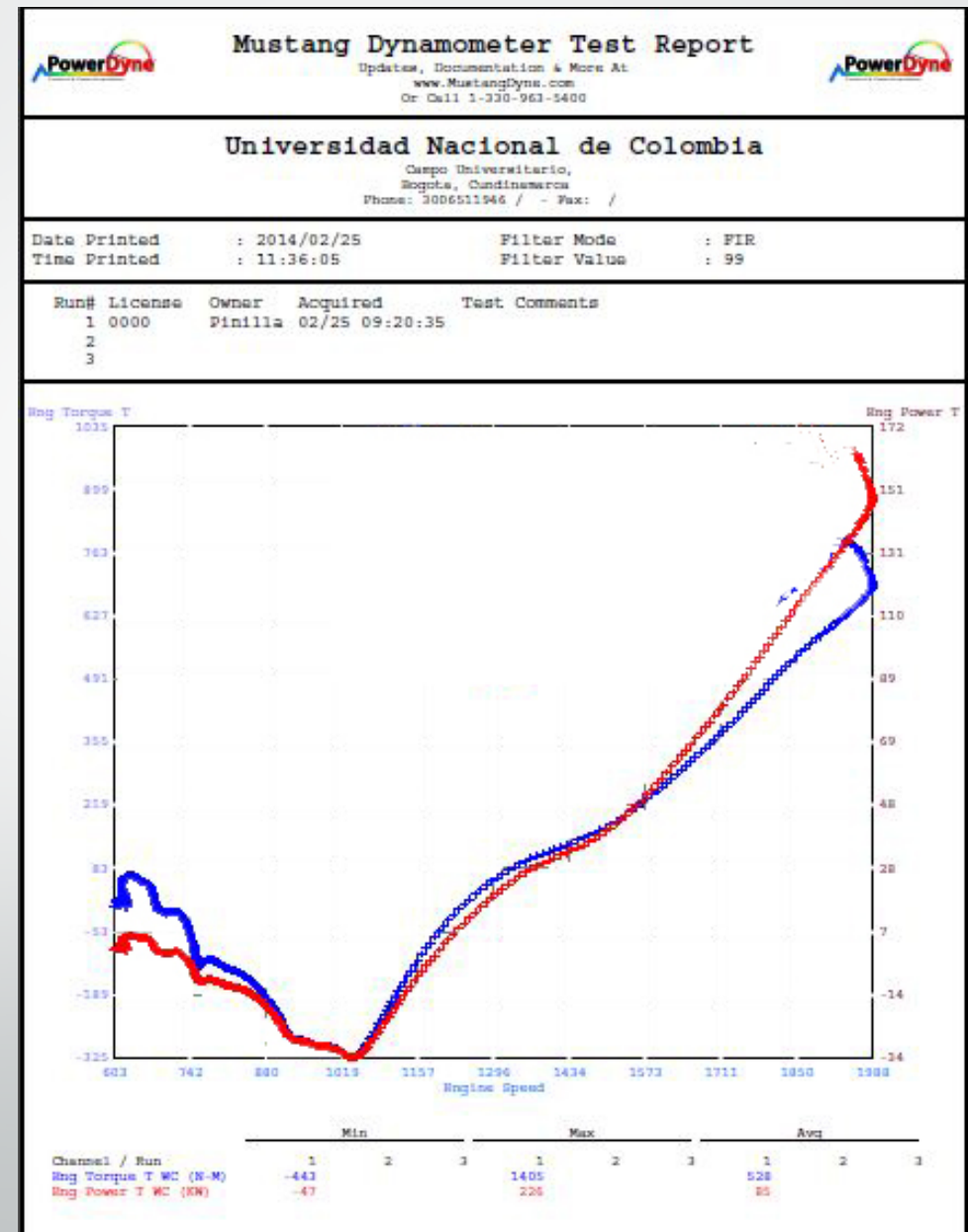


DYNO Specifications
Mustang Dynamometer
MD – 400 HD Eddy Current Chassis Dynamometer
775 horsepower (578 kW) @ 100 mph (161 km/h),
cold condition

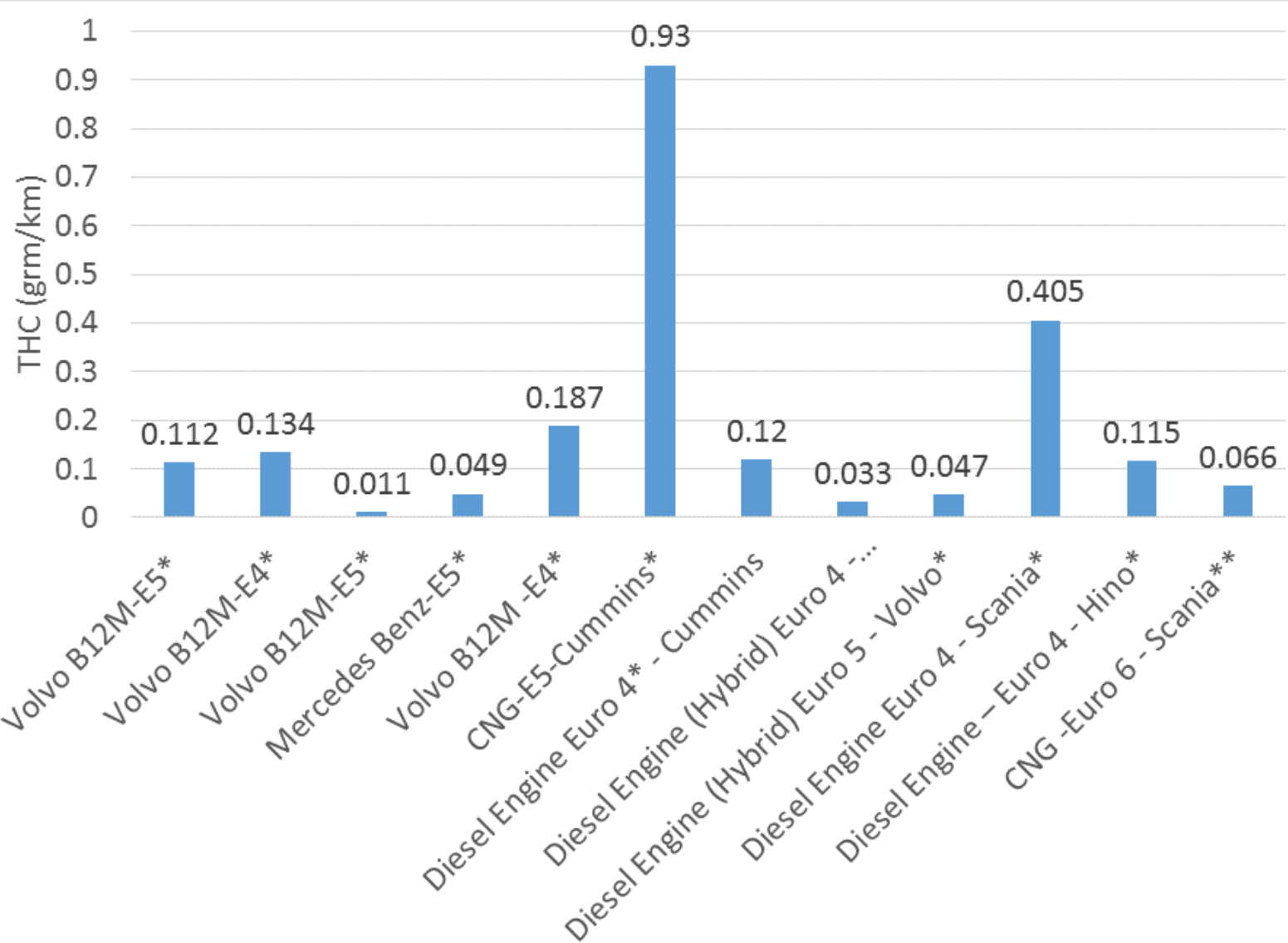


DYNO Procedure:

1. To run the vehicle in the fourth gear to get a relation 1:1 (engine/transmission)
2. To get the maximum power and torque increasing load.
3. To decrease the load up to 75, 50, 25 and 0%.



4. RESULTS (CNG-EURO VI BUS VS DIESEL EURO V AND IV BUSES)

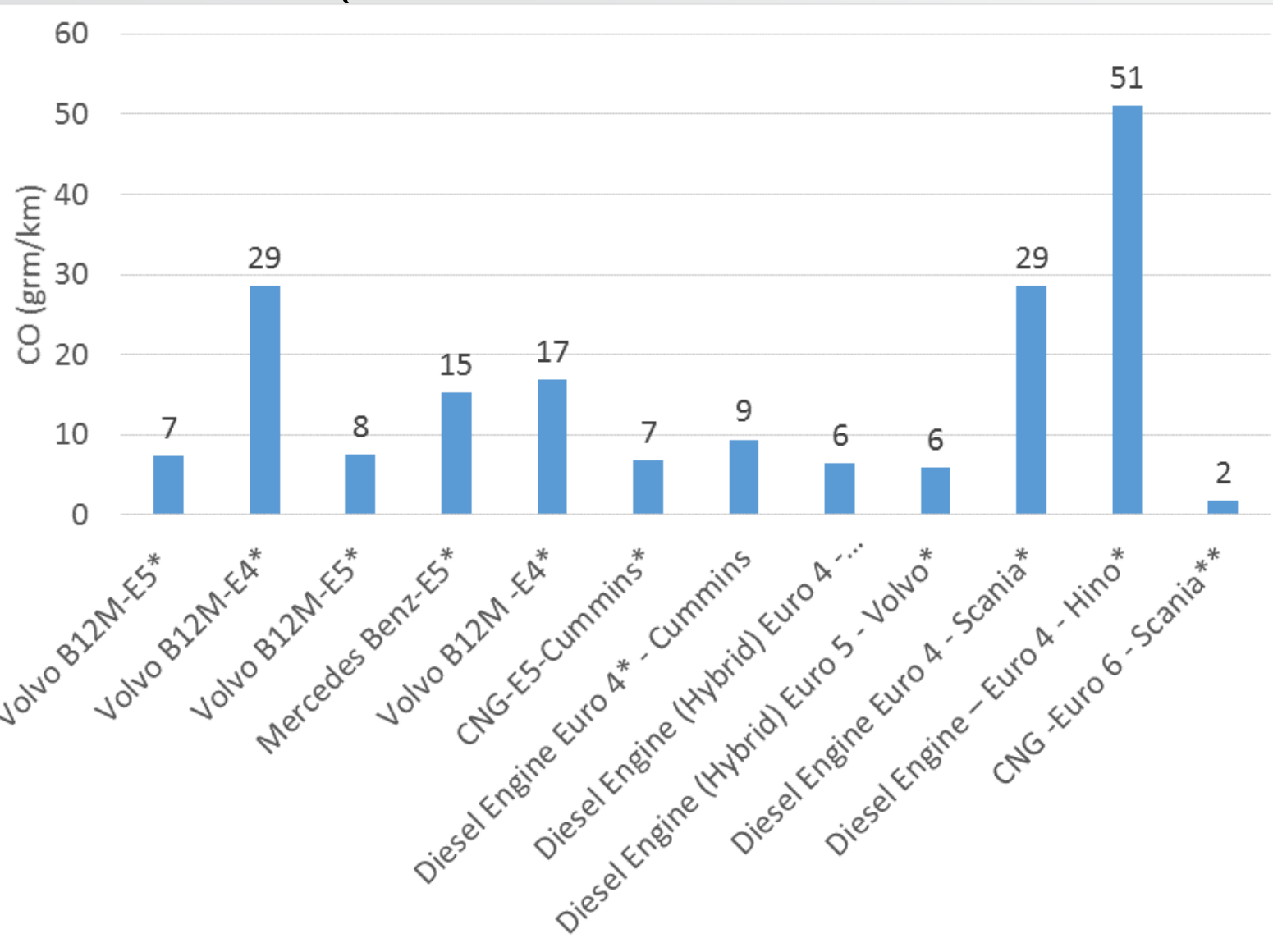


On-road testing

*Source: Contract # 013-2012.
Environmental Secretary of Bogota
and National University of Colombia
Articulated Buses for 160 and 260
passengers.

**Source: National University of
Colombia, 2014

4. RESULTS (CNG-EURO VI BUS VS DIESEL EURO V AND IV BUSES)

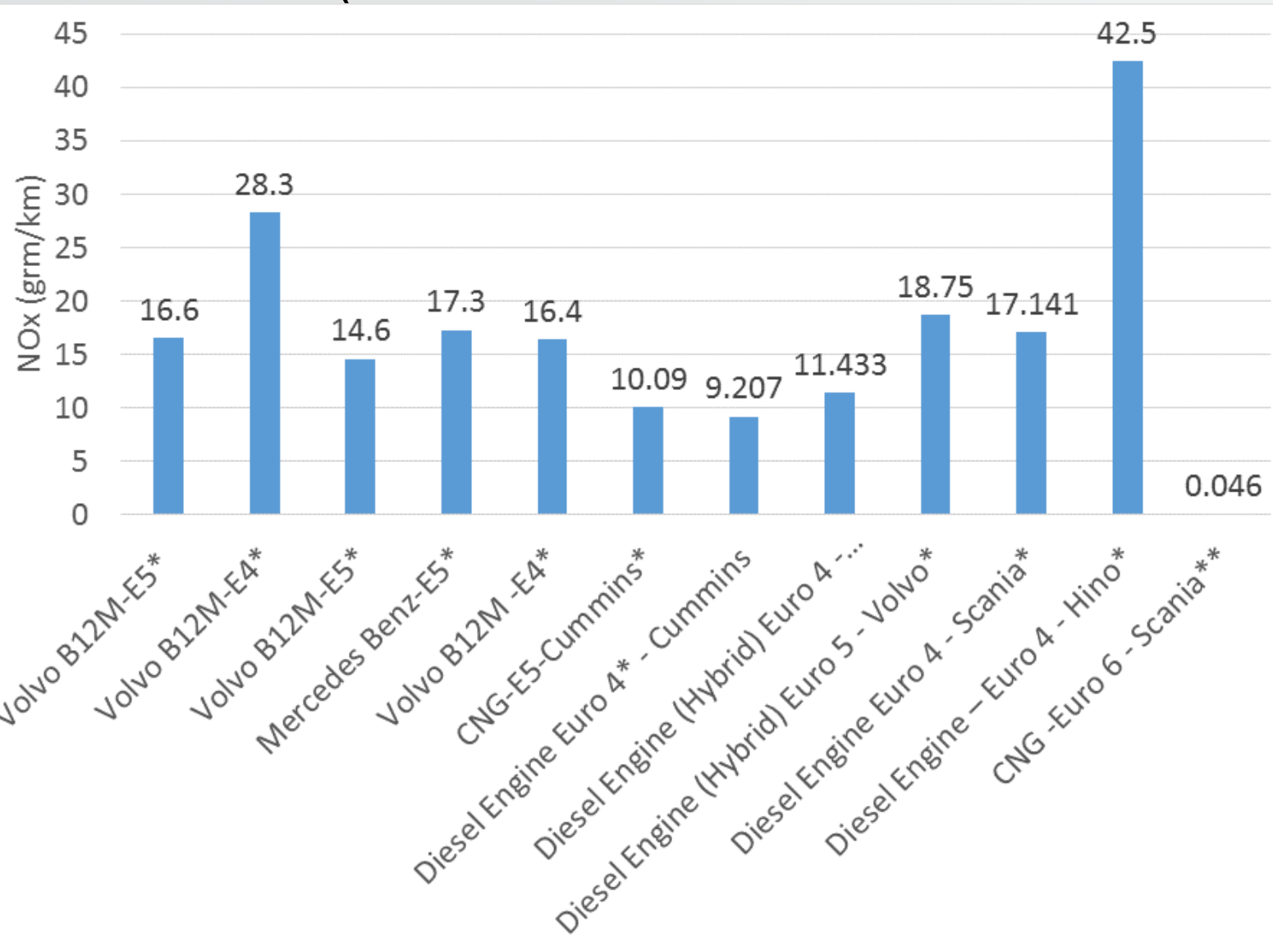


On-road testing

*Source: Contract # 013-2012.
Environmental Secretary of Bogota
and National University of Colombia
Articulated Buses for 160 and 260
passengers.

**Source: National University of
Colombia, 2014

4. RESULTS (CNG-EURO VI BUS VS DIESEL EURO V AND IV BUSES)

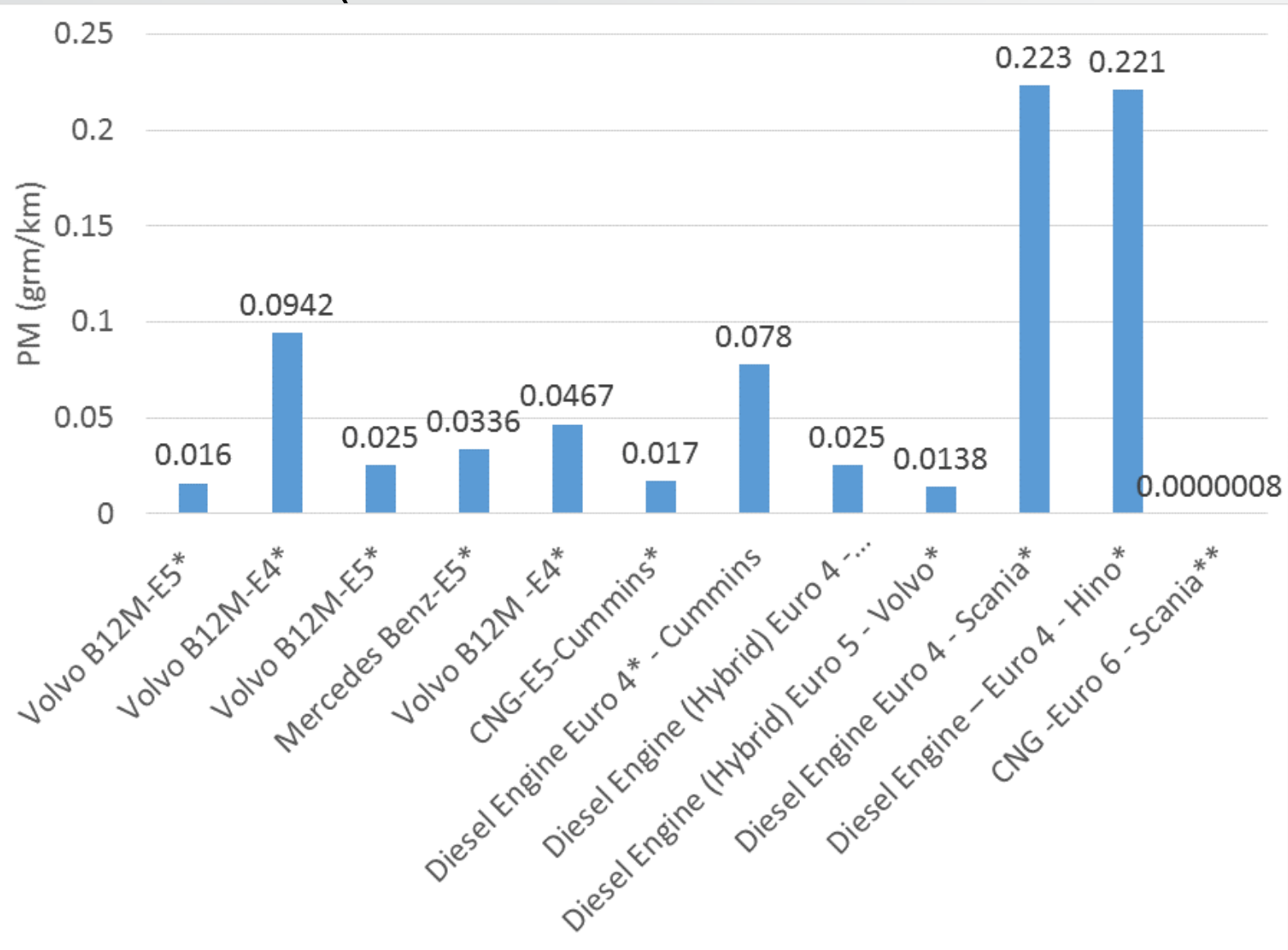


On-road testing

*Source: Contract # 013-2012.
Environmental Secretary of Bogota
and National University of Colombia
Articulated Buses for 160 and 260
passengers.

**Source: National University of
Colombia, 2014

4. RESULTS (CNG-EURO VI BUS VS DIESEL EURO V AND IV BUSES)

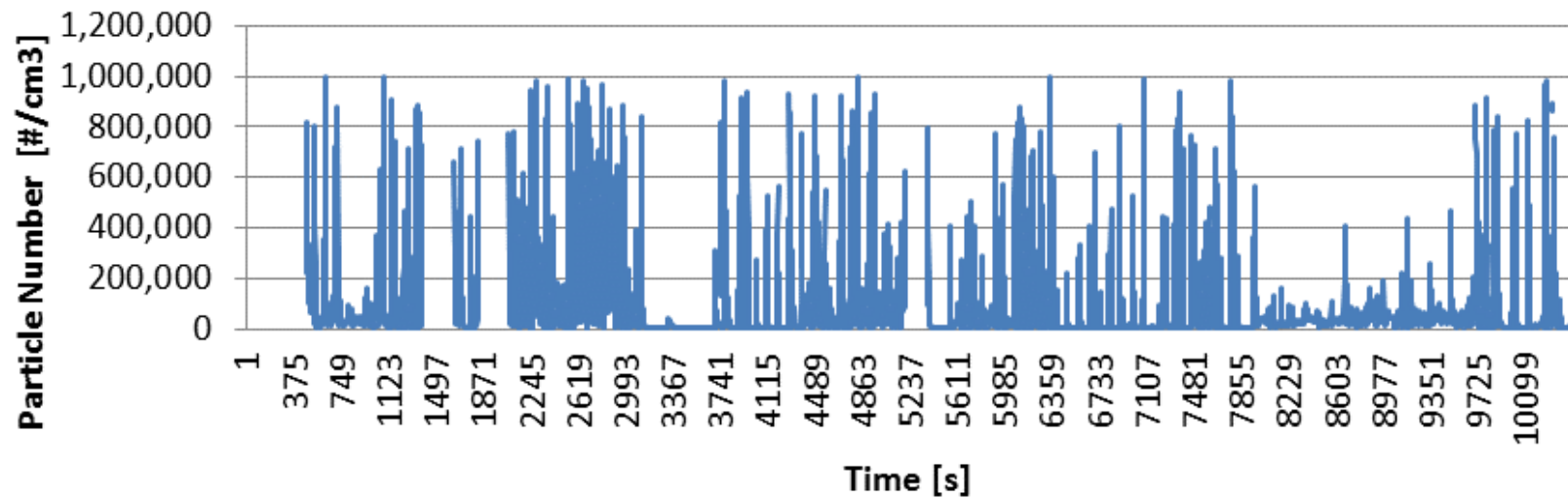


On-road testing

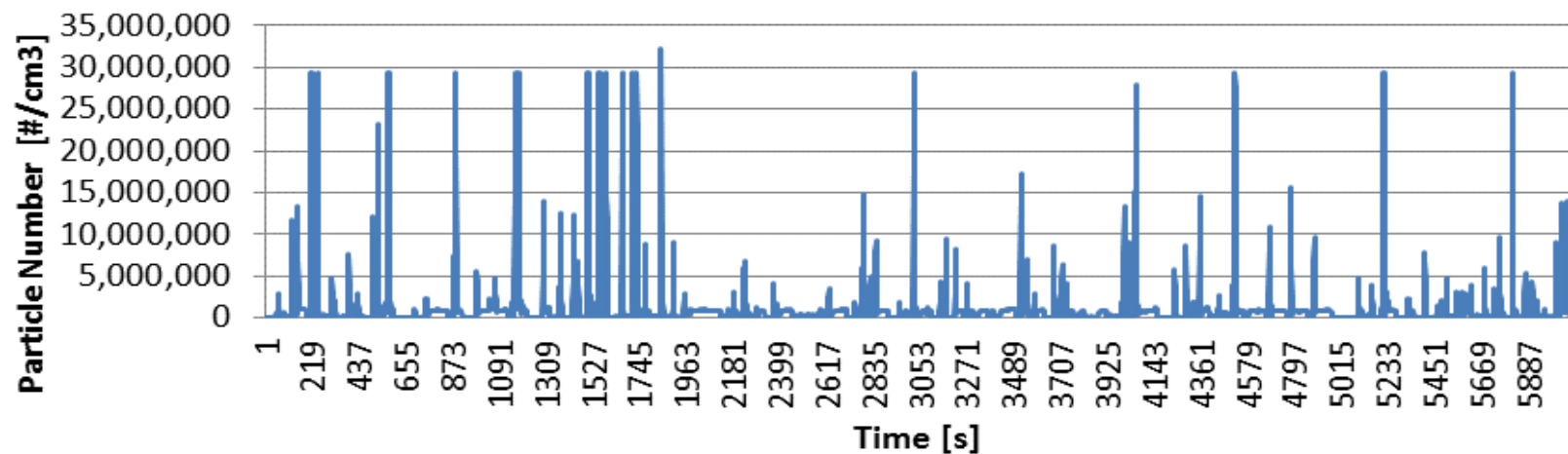
*Source: Contract # 013-2012.
Environmental Secretary of Bogota
and National University of Colombia
Articulated Buses for 160 and 260
passengers.

**Source: National University of
Colombia, 2014

4. RESULTS (CNG-EURO VI BUS VS DIESEL EURO IV BUSES)



The maximum particle number per cm^3 for the CNG **Euro 6** Bus was 950,000. The average was 56,000



The maximum particle number per cm^3 for the Diesel **Euro IV** Bus was 32 millón. The average was 13 millon

4. RESULTS (CNG-EURO VI BUS VS DIESEL EURO V AND IV BUSES – ON ROAD TESTING)

Bus	Fuel Consumption (gal/100 km)*	Actual Weight (kg)*	Gal/ton*
CNG-Euro 5-Cummins	16.09	17,300	0.930
Diesel Engine (Hybrid) - Youngman	10.32	16,780	0.615
Diesel Engine-Euro 4-Cummins	16.99	17,310	0.982
Diesel Engine – Euro 5 (Hybrid) Volvo	11.12	17,100	0.649
Diesel Engine – Euro 4 – Hino	14.52	16,020	0.906

Tested Vehicle	Fuel Consumption (gal/100 km)	Actual Weight (kg)	Gal/Ton**
Scania K340	16.65	21720	0.767

*Source: Contract # 013-2012. Environmental Secretary of Bogota and National University of Colombia

**Source: National University of Colombia, 2014

4. Results (CNG-EURO VI BUS VS DIESEL EURO II, III, AND IV BUSES – DYNO TESTING)

Plate	Id.	Brand	Model	PN [#/cm ³]			
				0%	25%	50%	75%
VEF604	B115	Volvo B12M	DH12C (Euro III)	1,83E+07	3,20E+07	4,02E+07	6,41E+07
SHN775	T086	Volvo B10M	DH10A (Euro II)	2,55E+06	5,23E+06	4,23E+06	7,51E+06
VEE166	S157	Scania K94IA	DC9 21310 (Euro III)	4,70E+06	4,21E+07	4,51E+07	5,87E+06
WCR421	--	MB	Atego 1006 Euro IV	2,32E+06	3,57E+06	5,36E+06	2,80E+06
SIE057	U130	MB	OM 449 LA (Euro II)	1,01E+06	4,54E+06	3,23E+06	16,01E+06
VHM490	M028	VOLVO B10M	DH10A (Euro II)	2,35E+06	4,22E+06	3,91E+06	-

Source: Contract # 015-2013. Environmental Secretary of Bogota and National University of Colombia

Vehicle	Número de Partículas		
Scania K340 (Euro VI)	0%: 1,8 E+04	25%: 2,2 E +04	50%: 1,7 E + 04

Source: National University of Colombia, 2014

5. CONCLUSIONS

- Fuel Efficiency of the CNG Euro 6 Scania bus is 0.76 equivalent diesel gallons per ton. Fuel Efficiency of Diesel vehicles Euro IV and V is roughly 0.9 gallons per ton (18% higher compared to Euro 6 Bus). A Hybrid Vehicle 0.64 gallons per ton (14% lower compared to Euro 6 Bus)
- Total Hydrocarbons, Carbon Monoxide, Nitric Oxides, and Particle Matter are extremely lower for the CNG Euro 6 Bus compared to Diesel Euro IV and V Buses.
- Particle Number Concentration of CNG Euro 6 bus was extremely lower compared to Diesel Euro II, III, IV and V buses. Euro 6 technology emits in the order of 10^4 particles per cubic centimeter and Euro 2, 3, 4, and 5 emit in the order to 10^6 particles per cubic centimeters.

6. ACKNOWLEDGMENTS

We thank to:

- Scania staff.
- Gas Natural S.A. – ESP (Natural Gas provider)
- Environmental Secretary of Bogota.
- Transmilenio S.A. Staff



7. QUESTIONS

?

