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

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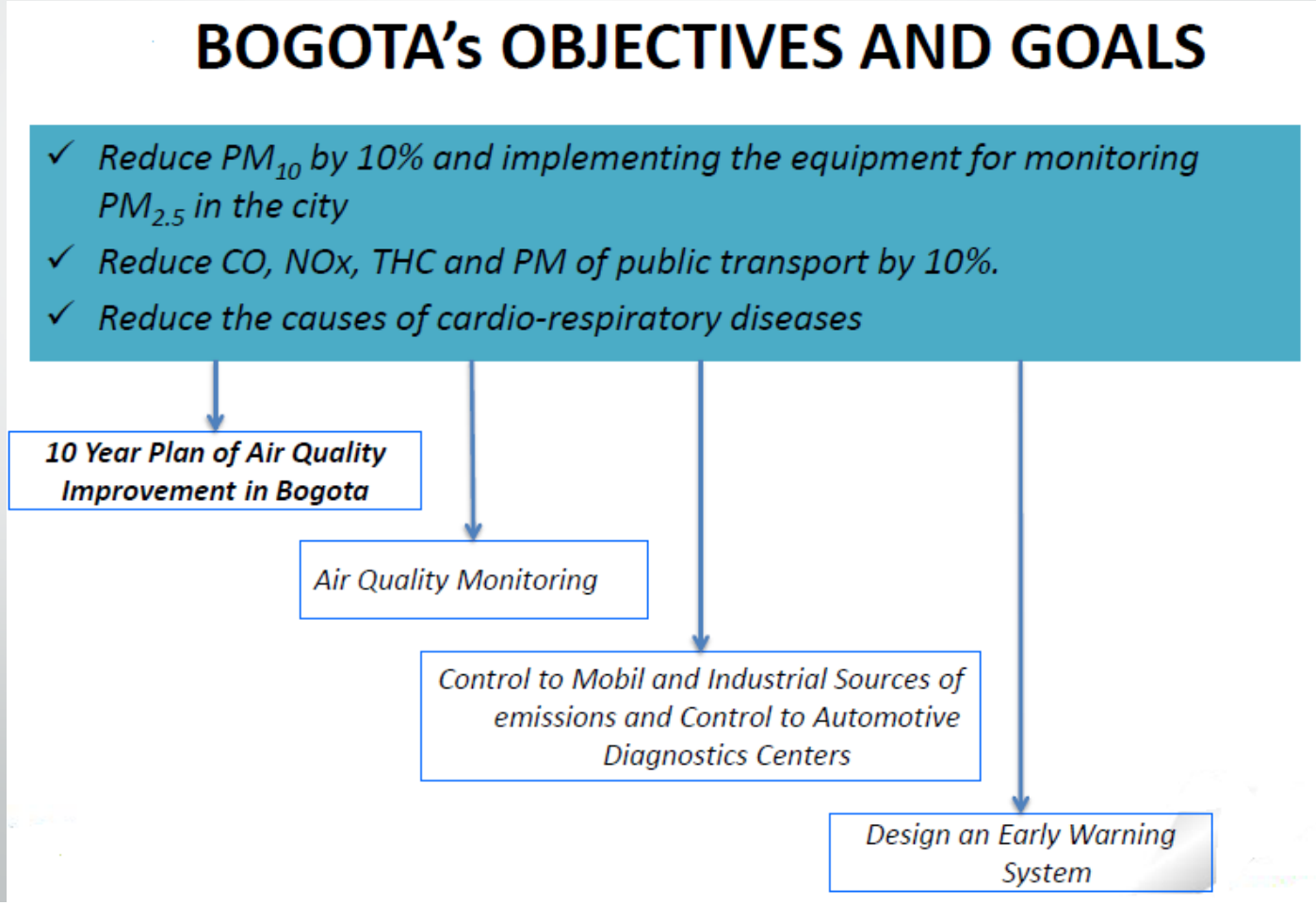
Content

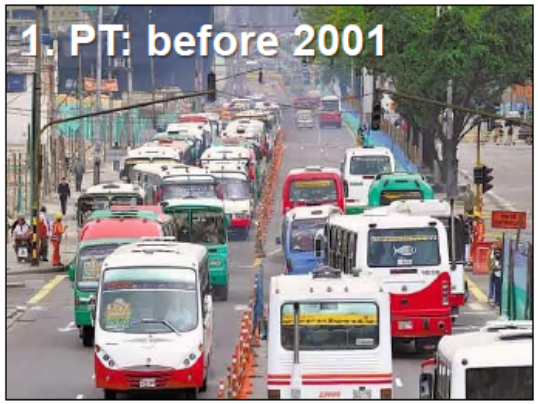
1. Introduction
2. Bus Specifications
3. Experimental Setup
4. Results
5. Conclusions
6. Acknowledgments
7. Questions

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.



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.

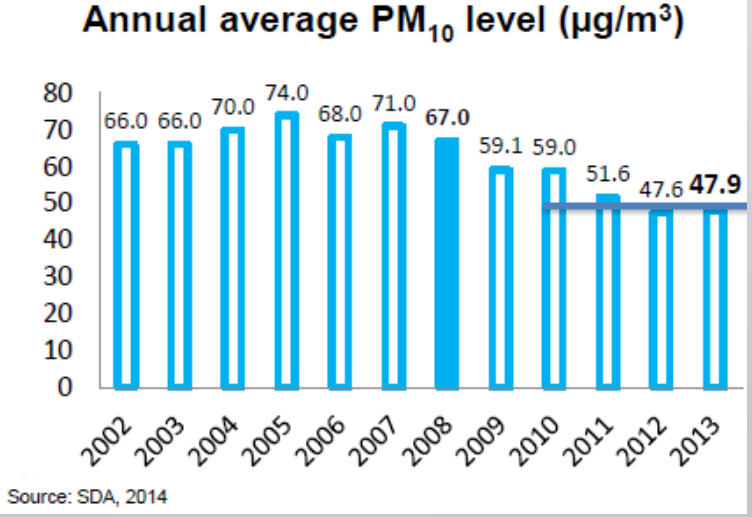
SECRETARÍA DISTRITAL DE AMBIENTE

BOGOTÁ HUMANA

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



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 EFFICIENY
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 (#/cm3)
- average size (nm), 10…700 nm (within mode diameter of 10…300 nm)
- calculated particle mass (mg/m3)
- LDSA–Lung Deposition Surface Area (µm2/cm3)

SEMTECH-G: gas emissions testing monitor measures emissions of CO, CO_2, total Hydrocarbons (THC), NO, and NO_2. The Semtech-G unit uses infrared absorption technology to measure CO and CO_2, ultraviolet absorption technology to measure NO and NO_2, 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)

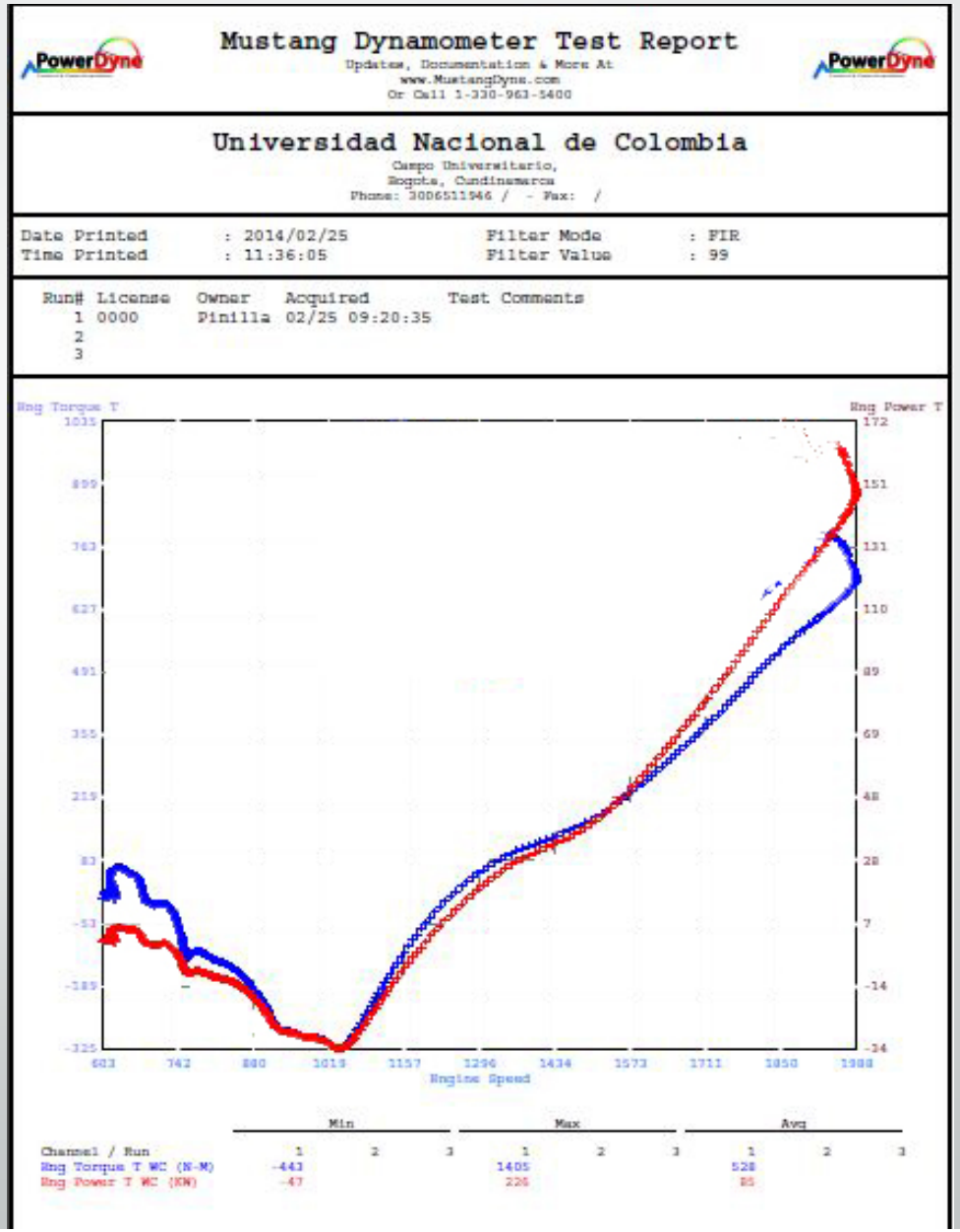
Fourth Zone: Highway (Average Speed: 30 km/h)
The bus stops at all bus stops for 2 minutes.
There are 62 bus stops.
Data Collected: Total Distance: 798 km, Total Time: 42:15 [hh:mm]

3. EXPERIMENTAL SETUP (DYNO TESTING)

DYNO Specifications
Mustang Dinamometer
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%.



Mustang Dynamometer Test Report

Updates, Documentation & More At
www.MustangDyno.com
Or Call 1-330-963-5400

Universidad Nacional de Colombia

Campo Universitario,
Bogota, Cundinamarca
Phone: 3006511946 / - Fax: /

Date Printed	: 2014/02/25	Filter Mode	: FIR
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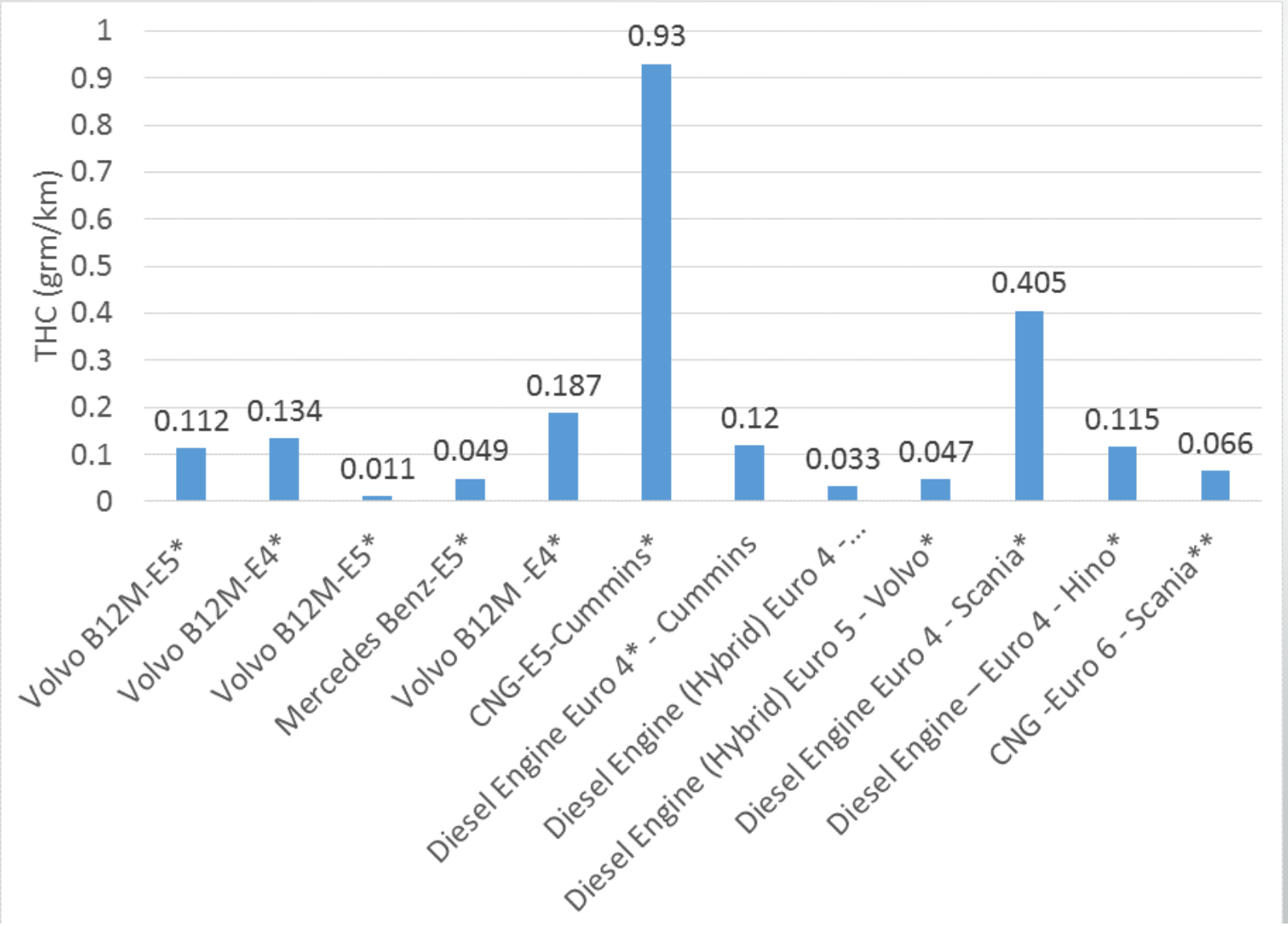
Run#	License	Owner	Acquired	Test Comments
1	0000	Pinilla	02/25 09:20:35	
2				
3				

Channel / Run	Min 1	Min 2	Min 3	Max 1	Max 2	Max 3	Avg 1	Avg 2	Avg 3
Eng Torque T WC (N-M)	-443			1405			528		
Eng Power T WC (KW)	-47			226			85		

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

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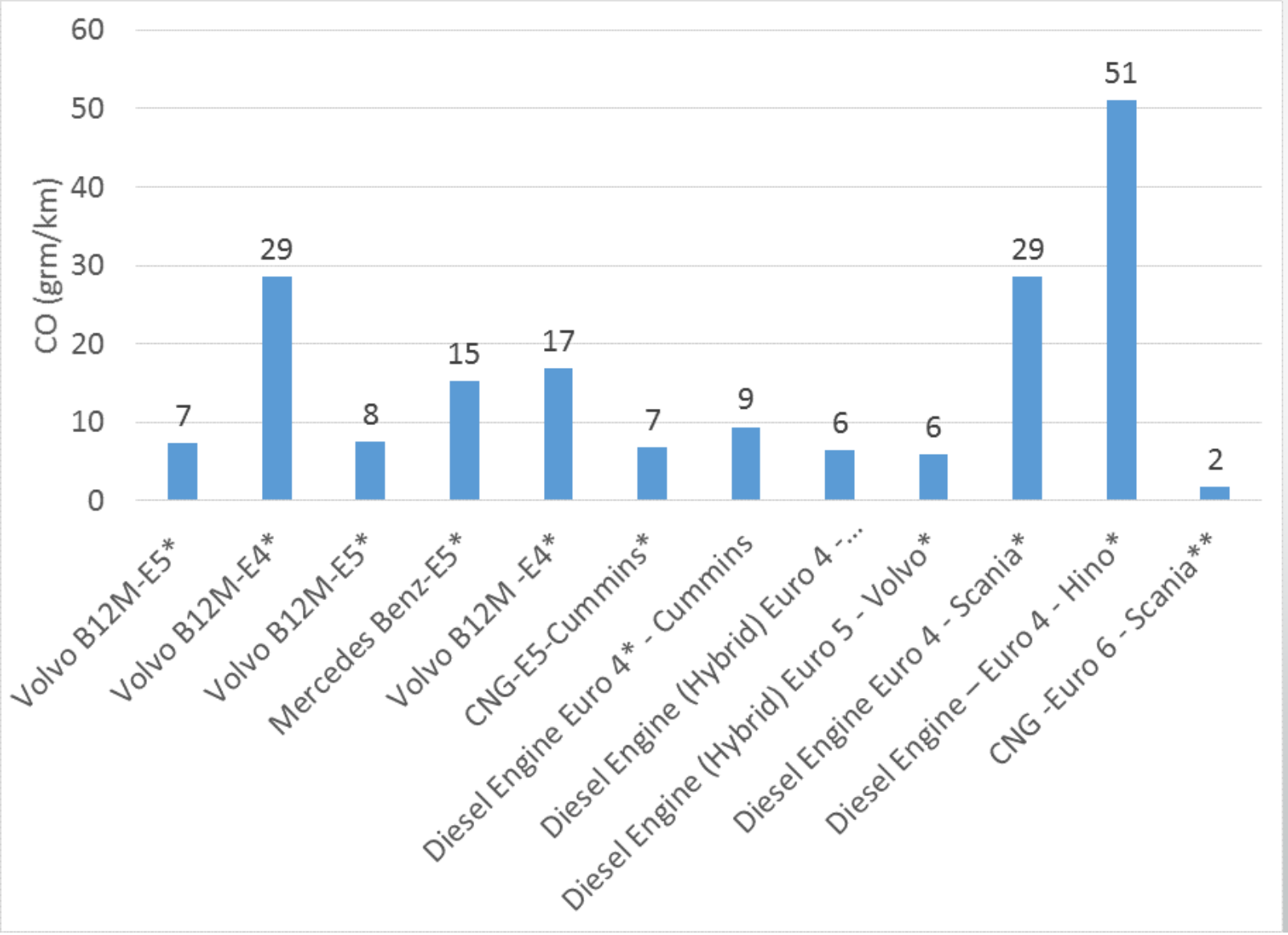

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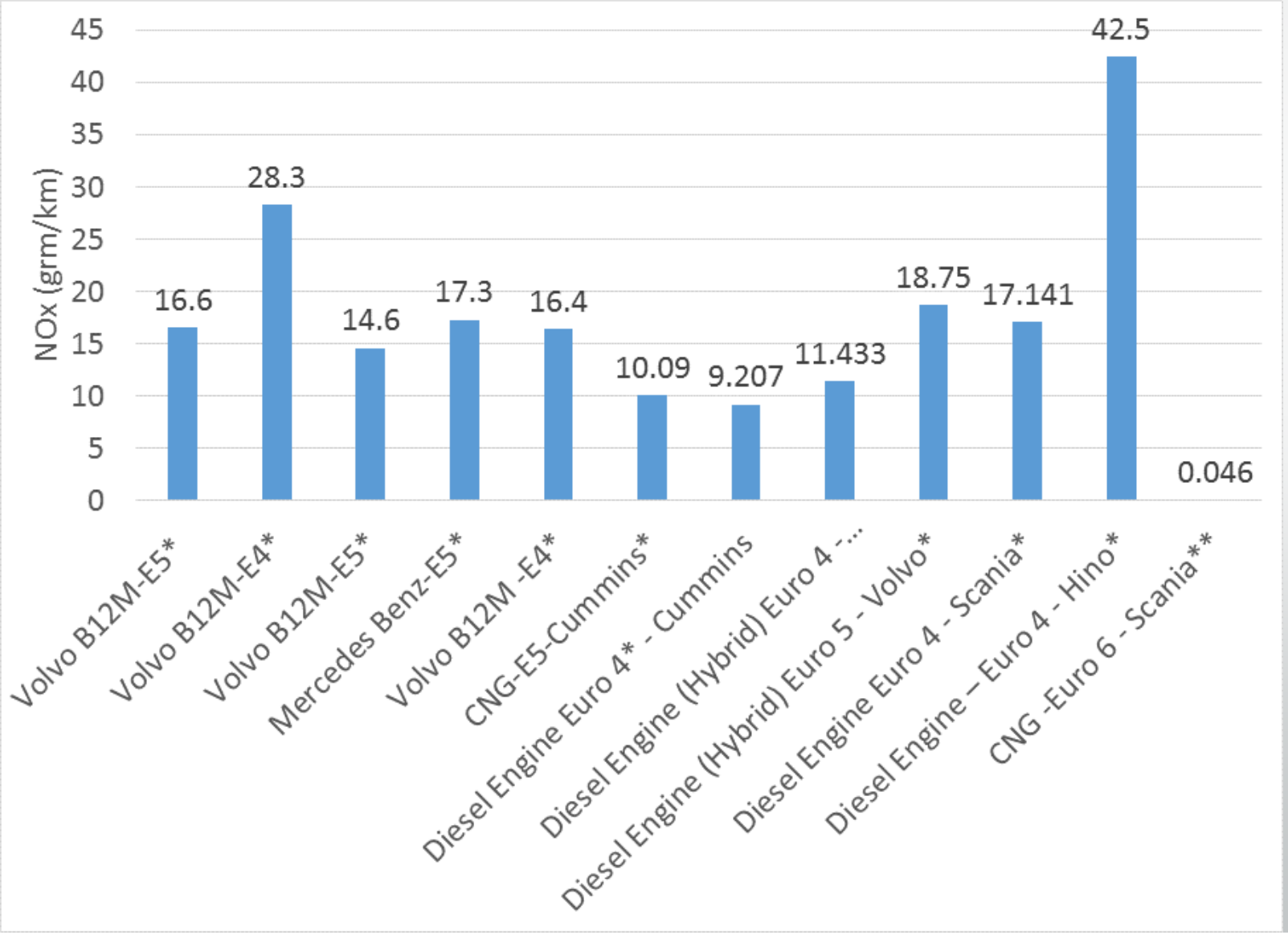

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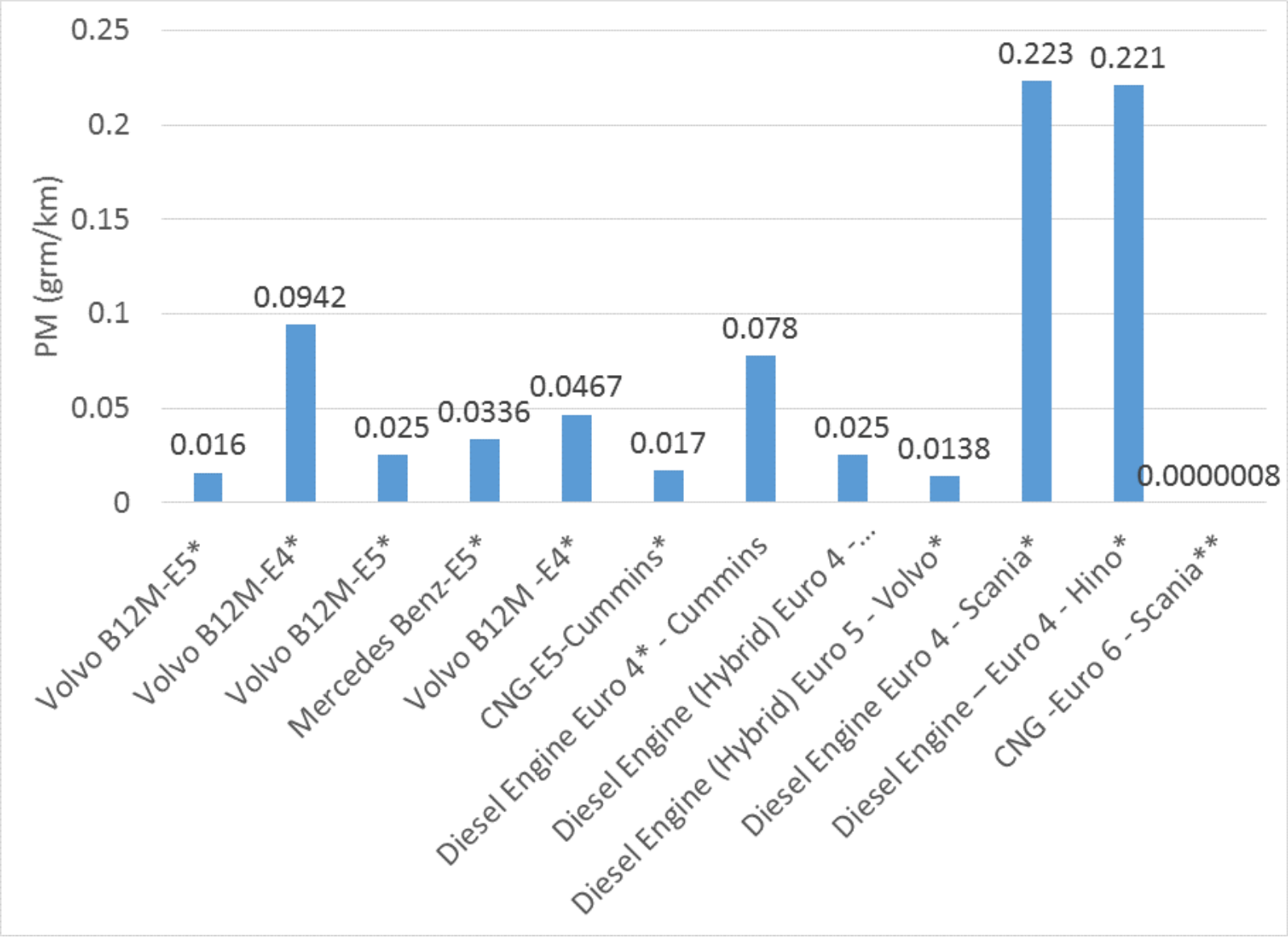

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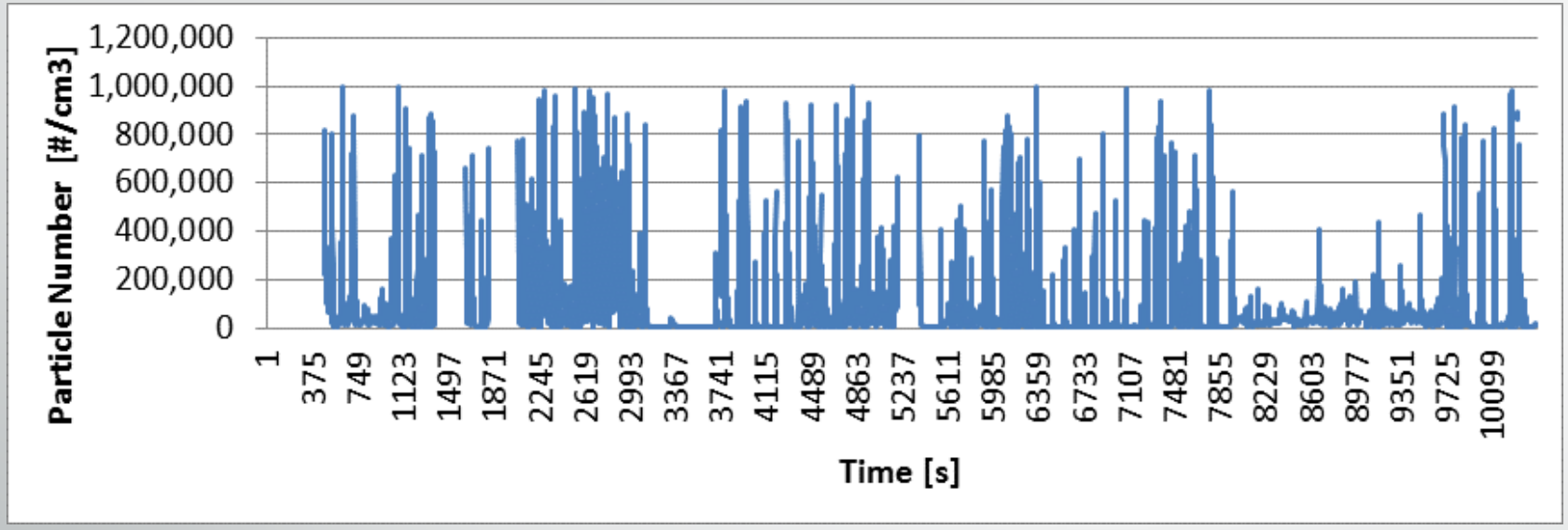
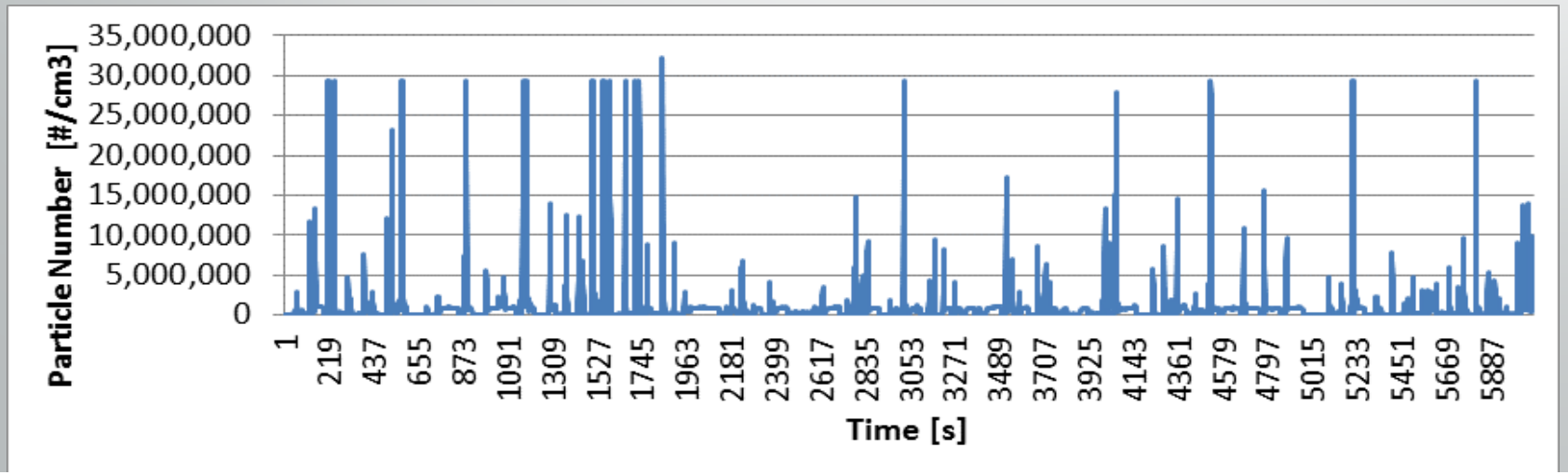


The maximum particle number per cm^3 for the CNG **Euro 6** Bus was 950,000. The average was 56,000



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 [#/cm3]			
				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

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