Santiago - Bogotá – Mexico – Sao Paulo --- within VERT- SDC

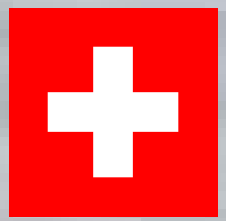
Swiss Agency for Development and Cooperation

CALAC

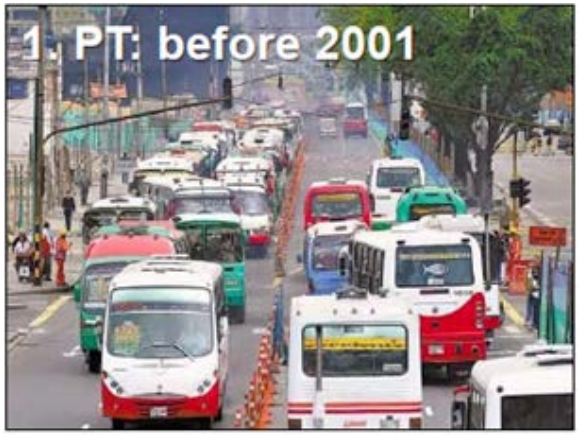
Clean Air for Latinamerican Mega Cities

Air Quality Challenges of a Megacity at 2600 m above Sea Level

A.Mayer



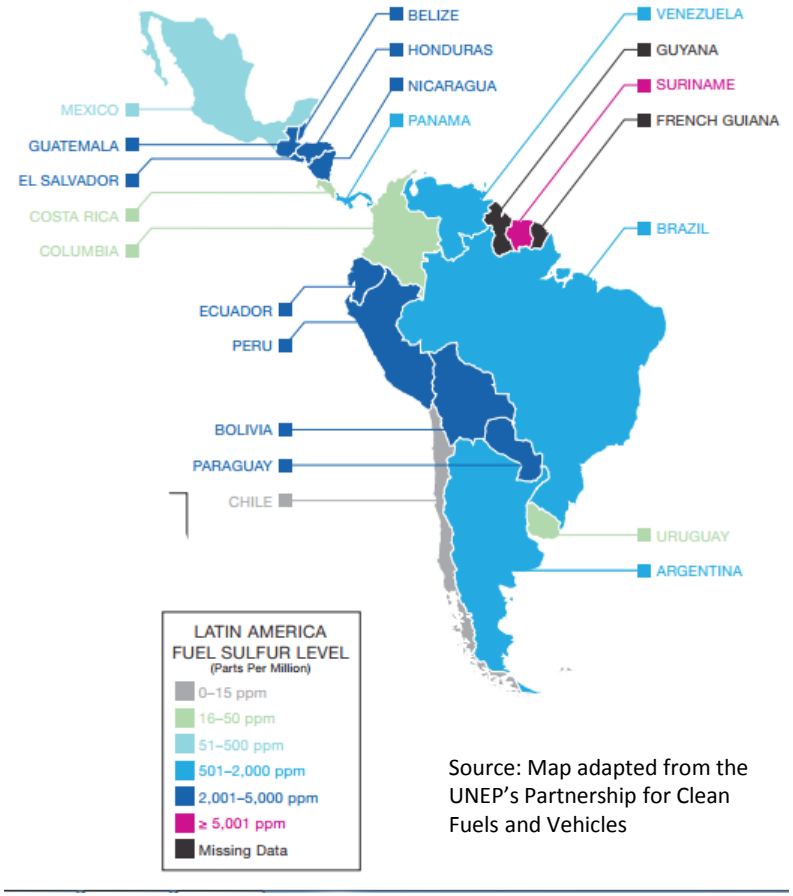
Last Decade: What happened?



Pioneered in the mid-sized Brazilian city of Curitiba in the 1970s, Bus Rapid Transit increased bus speeds and improved road safety by placing high-capacity buses within committed bus lanes which channel buses to a series of fixed stations, similar to light-rail or metro systems. Inspired by the success of Curitiba's system, cities such as Mexico City, Bogotá and Quito have more recently made BRT the linchpin of their transit network, to considerable acclaim from the riding public and international observers alike.

Robert Banick, A Research Assistant at the Council on Hemispheric Affairs (COHA)
http://www.citymayors.com/transport/brt-latin-america.html

Fuel Quality



Source: Map adapted from the UNEP's Partnership for Clean Fuels and Vehicles

Diesel Fuel Standards have improved in many Latin America Countries during the last decade to fullfill engine manufacturers requirements.

Emission Standards in Latin America Cities

COUNTRY	National Annual PM_{10} and $PM_{2.5}$ Standards[27*]	Maximum Sulfur Level in Diesel Fuel	Road Sector Diesel Use (kilotons of oil equivalent by year)	Number of Registered Vehicles[28]	Emissions Standards for New Vehicles[29*]
ARGENTINA[30]	PM_{10}: None $PM_{2.5}$: None	1,500 ppm (500 in Buenos Aires, Rosario, Mar del Plata, and Bahía Blanca)	7,212 (2008)	11 MM (2011)	LDV, HDV, and Buses: Euro V[31]
BOLIVIA[32]	PM_{10}: 50 µg/m³ $PM_{2.5}$: None	5,000 ppm	1,058 (2010)	1.1 MM (2011)	Buses: Euro III (La Paz)[33]
BRAZIL	PM_{10}: 50 µg/m³ $PM_{2.5}$: None	1,800 ppm (Between 50 and 500 in major cities)[34]	28,732 (2009)[35]	64.8 MM (2010)[36]	LDV: Euro IV HDV: Euro V
CHILE	PM_{10}: 50 µg/m³ $PM_{2.5}$: 20 µg/m³	15 ppm[37]	3,534 (2010)[38]	3.4 MM (2010)[39]	LDV and MDV: Euro V HDV: Euro V (from Sept. 2014) Buses: U.S. 2004 NO_x / U.S. 2007 PM[40]
COLOMBIA[41]	PM_{10}: 50 µg/m³ $PM_{2.5}$: 25 µg/m³	50 ppm[42]	3,754 (2010)	7.2 MM (2011)	LDV: Euro IV HDV: Euro IV (from 2015) Buses: Euro II
ECUADOR[43]	PM_{10}: 50 µg/m³ $PM_{2.5}$: 15 µg/m³	5,000 ppm (500 in Quito and Cuenca)[44]	2,415 (2010)	1.4 MM (2011)	LDV: Euro I / U.S. 1987 HDV: Euro II / U.S. 1994

Source: Cleaning Up Latin America's Air: Reducing Black Carbon Emissions Can Benefit the Climate and Public Health Quickly

Emission Standards in Latin America Cities

COUNTRY	National Annual PM_{10} and $PM_{2.5}$ Standards[27*]	Maximum Sulfur Level in Diesel Fuel	Road Sector Diesel Use (kilotons of oil equivalent by year)	Number of Registered Vehicles[28]	Emissions Standards for New Vehicles[29*]
EL SALVADOR[45]	PM_{10}: 50 µg/m³ $PM_{2.5}$: 15 µg/m³	5,000 ppm	Levels unknown	0.7 MM (2012)	LDV: Euro I / U.S. 1987
GUATEMALA[46]	PM_{10}: None $PM_{2.5}$: None	5,000 ppm	Levels unknown	2.1 MM (2010)	None
HONDURAS[47]	PM_{10}: None $PM_{2.5}$: None	5,000 ppm	Levels unknown	1.2MM (2012)	None
MEXICO	PM_{10}: 50 µg/m³ $PM_{2.5}$: 15 µg/m³	15 ppm, but most diesel is 300 ppm[48]	13,767 (2009)[49]	30.2 MM (2011)	All: Euro IV / U.S. 2004
NICARAGUA[50]	PM_{10}: 50 µg/m³ $PM_{2.5}$: None	5,000 ppm	Levels unknown	0.6 MM (2012)	None
PARAGUAY[51]	PM_{10}: None $PM_{2.5}$: None	2,500 ppm	1,039 (2010)	1.15 MM (2013)	None enforced
PERU[54]	PM_{10}: 50 µg/m³ $PM_{2.5}$: 25 µg/m³	5,000 ppm (15 in Lima and Callao)	3,426 (2010)	2.6 MM (2011)	LDV and HDV: Euro III Buses: Euro IV (Lima)
URUGUAY[52]	PM_{10}: None $PM_{2.5}$: None	50 ppm[53]	582 (2010)	1.6MM (2011)	All: Euro III
VENEZUELA	PM_{10}: 50 µg/m³ $PM_{2.5}$: None	2,000 ppm[54]	2,909 (2010)[55]	4.4 MM (2011)	HDV: Euro I / U.S. 1991[56]

Source: Cleaning Up Latin America's Air: Reducing Black Carbon Emissions Can Benefit the Climate and Public Health Quickly

Pollution Ranking of Latin America Cities?

From Latin America, eight countries made the list of top 50 countries with the worst air pollution

1. **Peru** ranked 18th with a PM2.5 level of 38 ug/m3.
2. **Guatemala** tied in 21st place with a PM2.5 level of 33 ug/m3,
3. **Honduras** ranked as the 23rd worst for air pollution with a PM2.5 level of 32 ug/m3
4. **Chile** tied in 27th place with a PM2.5 level of 28 ug/m3
5. **Mexico** tied with a PM2.5 level of 27 ug/m3
6. **Bolivia** with a PM2.5 level of 27 ug/m3
7. **Venezuela** tied with a PM2.5 level of 26 ug/m3
8. **Colombia** tied in 38th place with a PM2.5 level of 24 ug/m3

Source: World Health Organization

Air Quality still very bad → actions urgently required

- Most of the Latin America Cities have implemented BRT´s as a solution for mobility.
- These BRT´s are using diesel fuel as a primary energy source.
- Diesel Fuel Quality has improved to achieve international standards issued by engine manufacturers.
- PM2.5, Black Carbon, and Particle Number have not decreased in many cities and it is important to push engine manufacturers, local authorities to implement clean technologies in the BRT´s of Latin America.

Air Quality Improvement

by DPF Filtration of Exhaust Gas of in-use public transport bus fleets

3500 Buses equipped with Diesel Particle Filters in Santiago de Chile

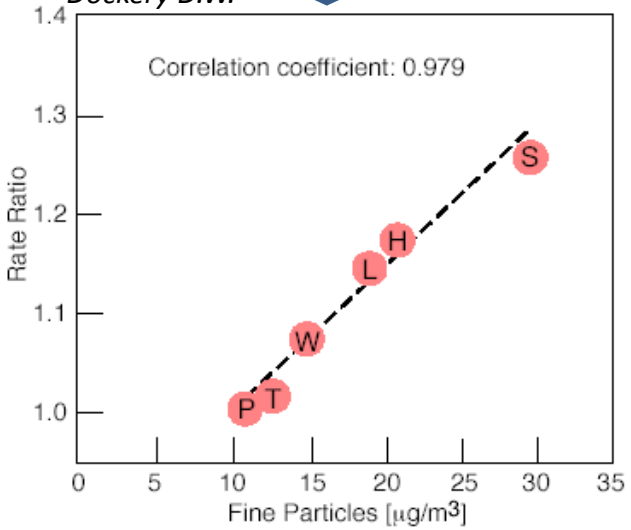
6000 Buses = 100 % in 2018

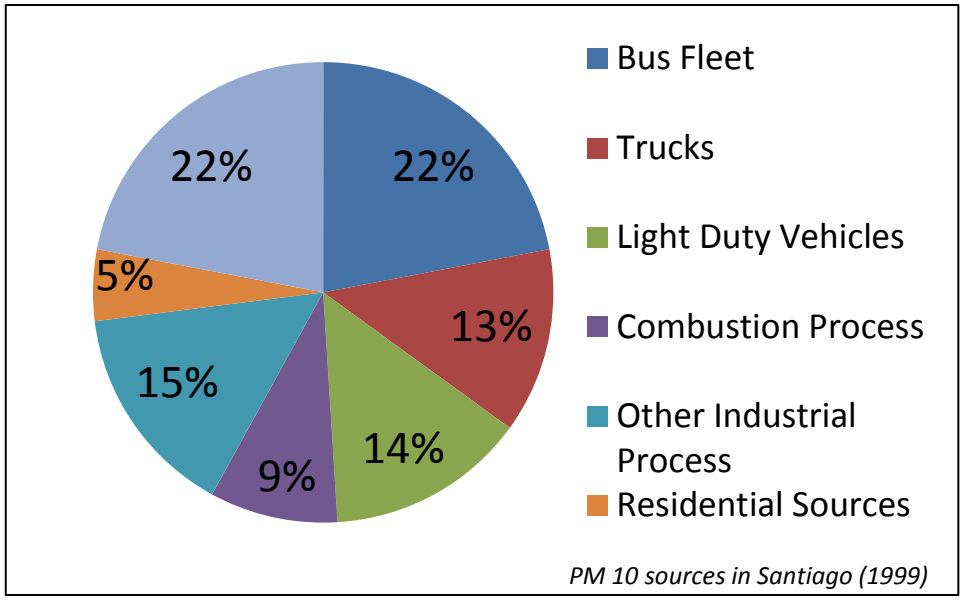
A.Mayer – Switzerland

A.Reinoso - Chile

Emissions, Air Pollution and Health Effects in Santiago

Dockery D.W.



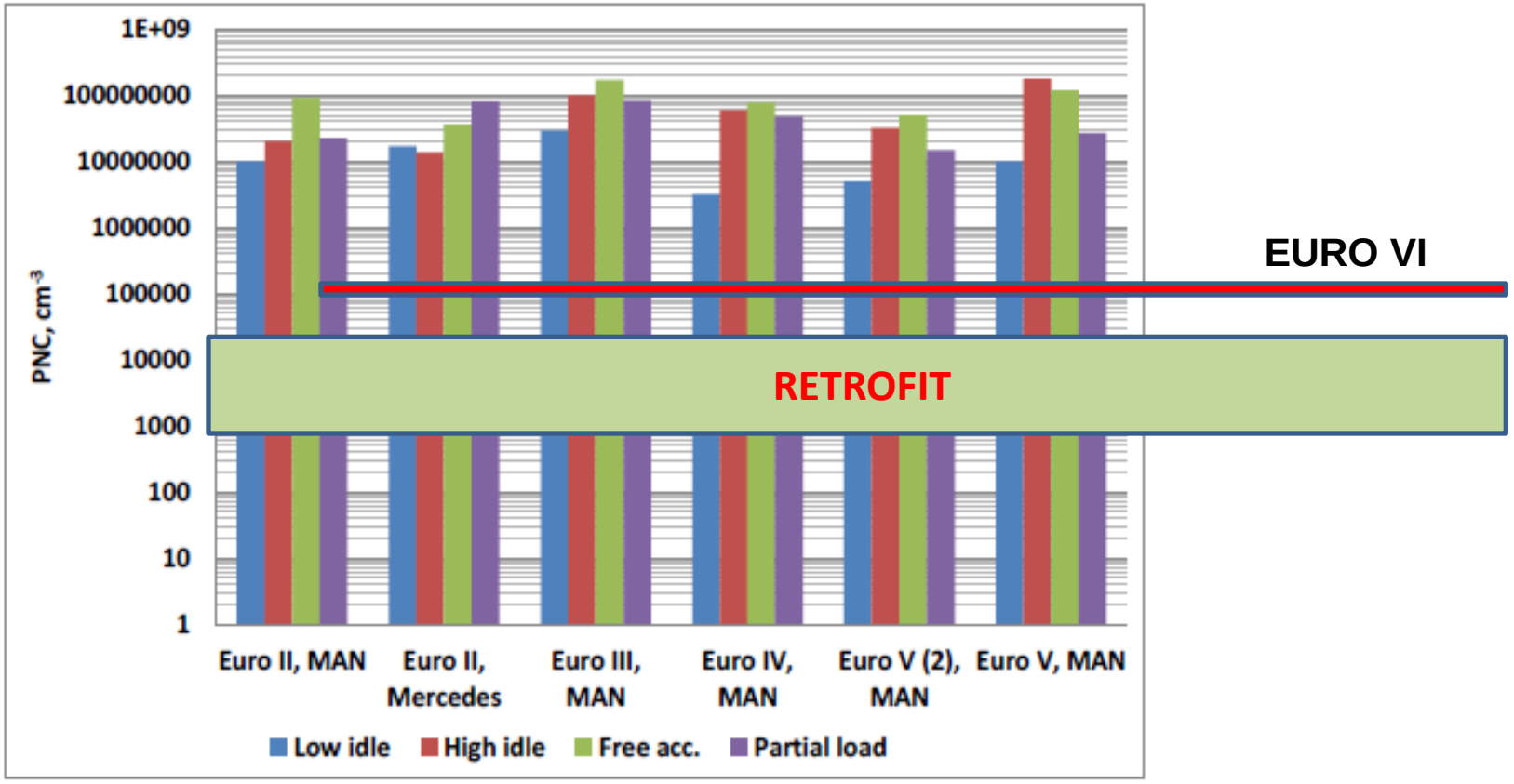


PM 10 sources in Santiago (1999)

800 premature deaths per year, attributable to air pollution of buses

According to WHO model application

Does current OEM Technology provide Solutions for the Reduction of Ultrafine Particle Emission ?

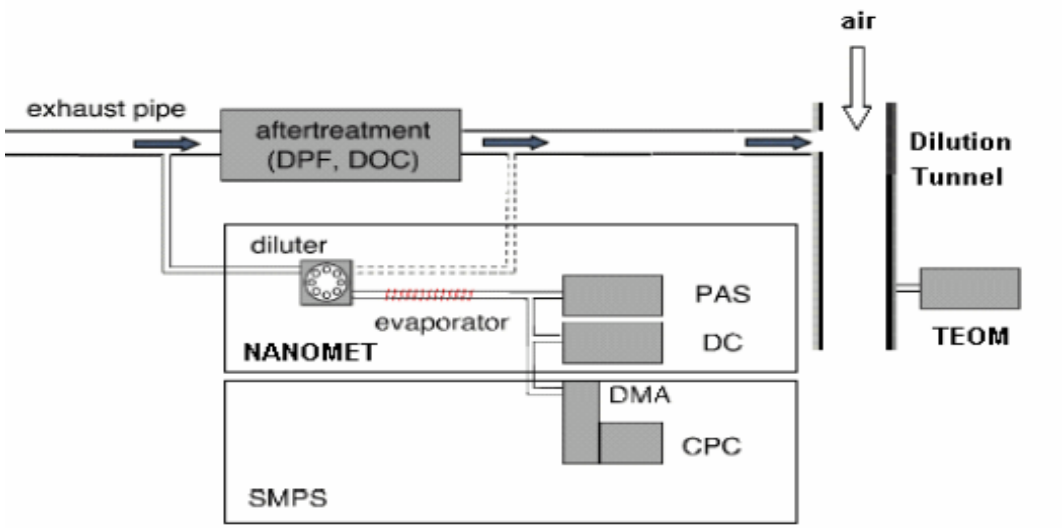


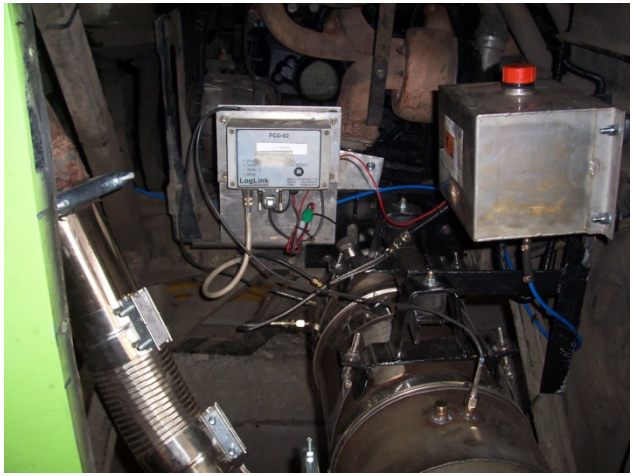
EURO V reduces mass PM but not number PN of UFP compared to II / III / IV

Euro VI will bring the solution with the mandatory introduction of particle filters

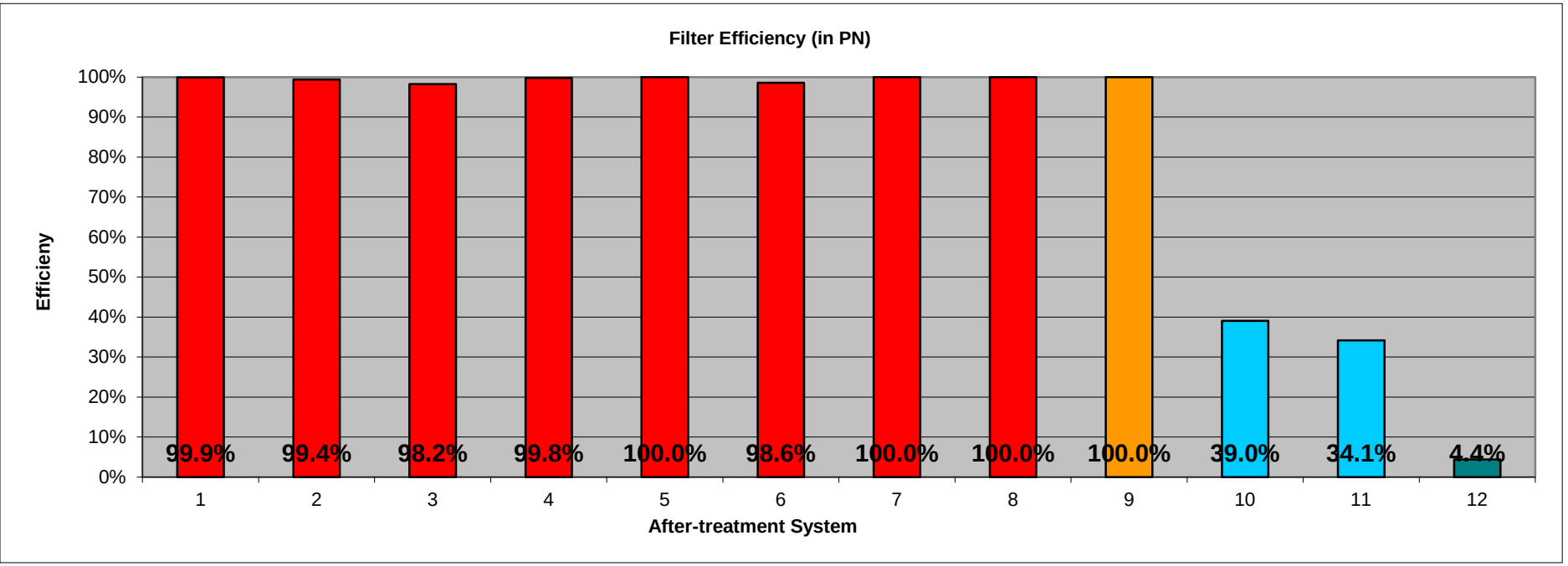
Retrofit can already today reach even better results on in-use engines Euro II to Euro V

Retrofit needs Technical Management





Results of the Santiago Pilot Test

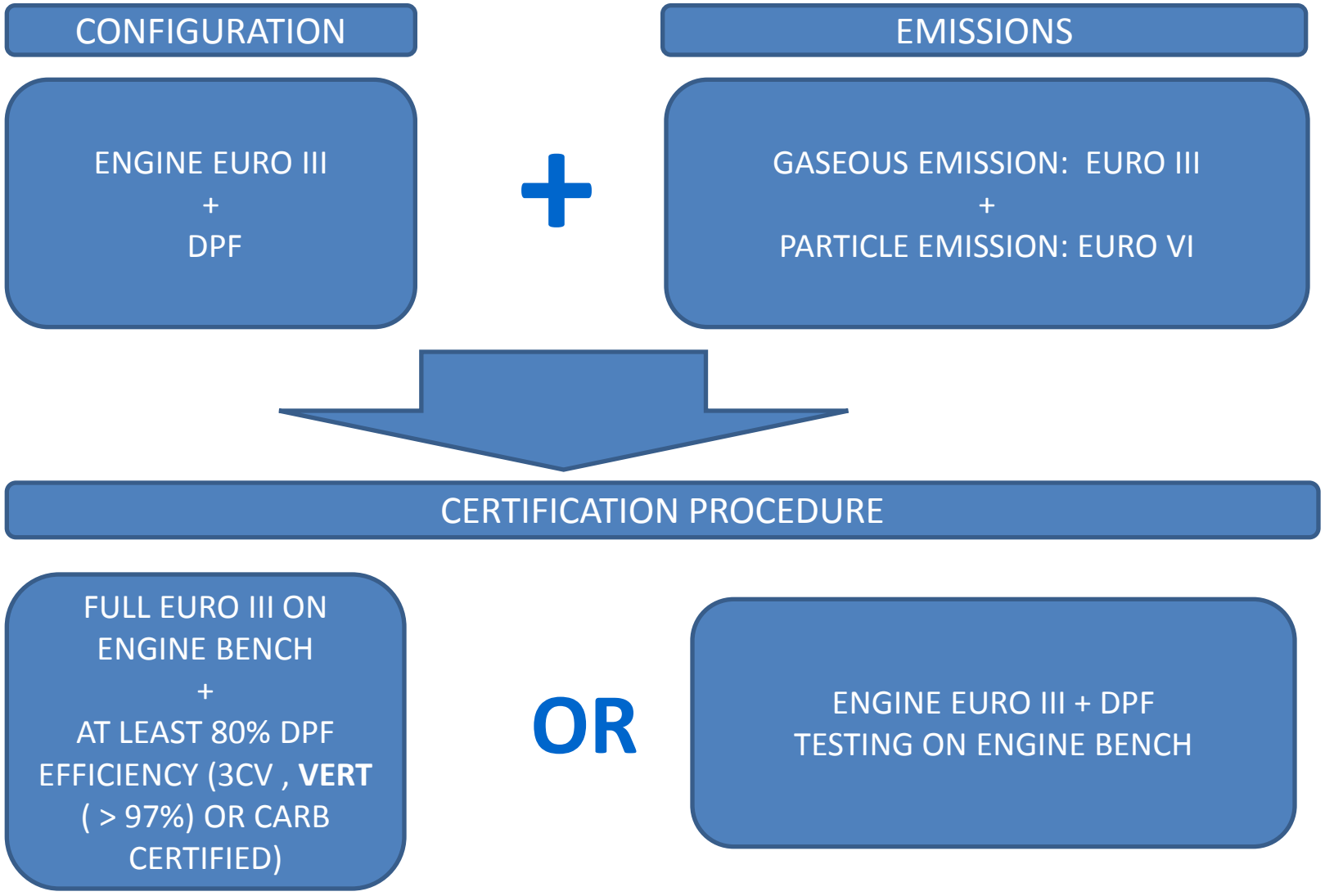


Sources 3CV-Chile.

One year testing of 12 typical bus systems with 8 different Particle Filters in 3CV-laboratories and in actual city driving permitted the selection of best available technology and the start of the Santiago filter policy process

EURO III plus DPF – the Policy for new buses

(Supreme Decree 49/2009 in force since 2010)



In-use Compliance Testing Results

up to 352’000 km in daily service

DPF Origin	Number of Buses	MILAGE [KM]			EFFICENCY [%]		
		Average	Max	Min	Average	Max	Min
OEM EQUIPPED	16	63,690	352,950	13,133	93%	98%	79%
RETROFITTED (*)	8	75,000	75,000	75,000	95%	98%	92%
Total	24	67,460	352,950	13,133	93%	98%	79%

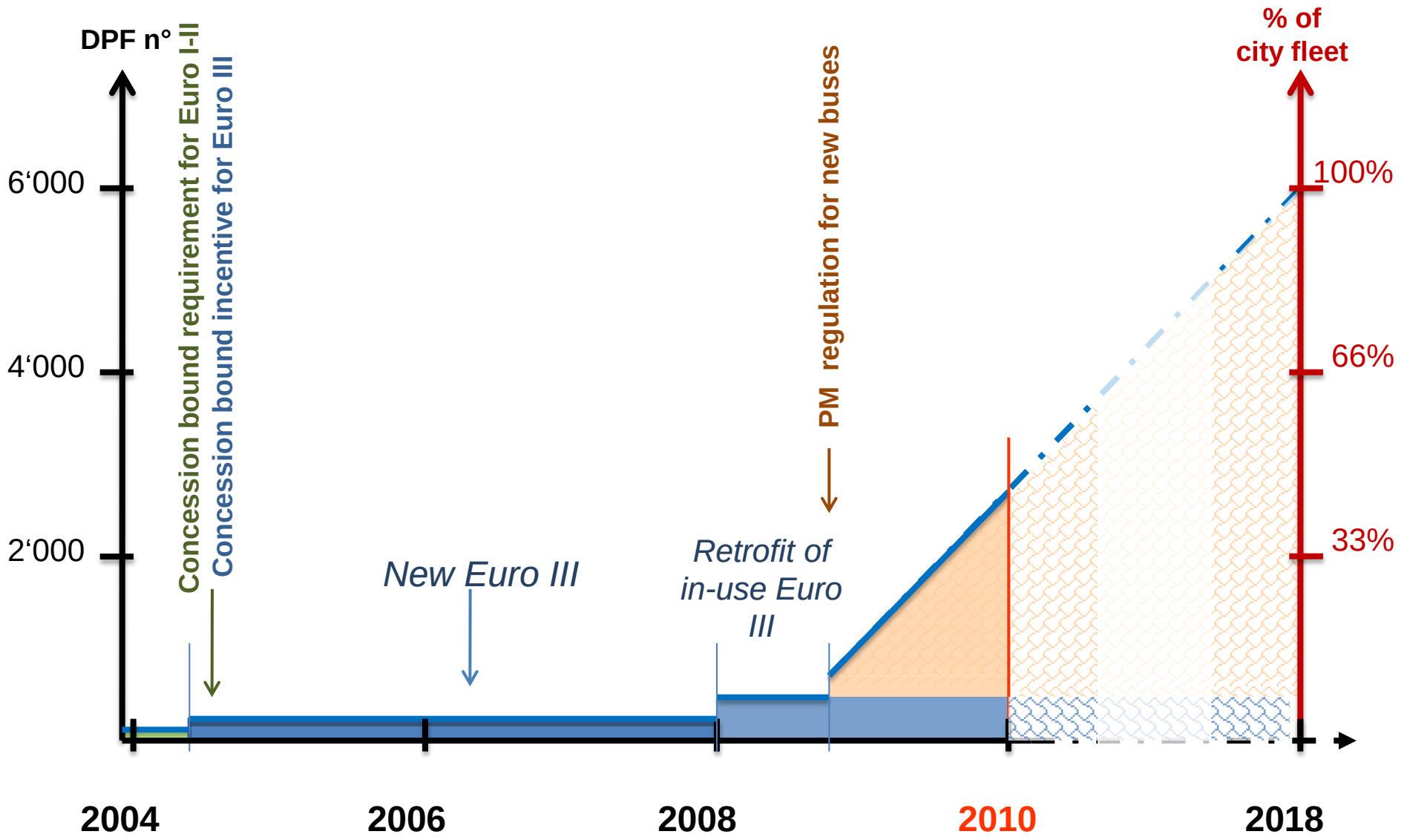
(*) Estimated for one years operation
Source 3CV-Chile data

Santiago’s new bus with DPF OEM equiped

Santiago’s retrofitted bus

Systematic Stepwise Approach

Pilot tests → **Concessions →** **Regulation →** **Full Scale Implementation**



UNIVERSIDAD NACIONAL DE COLOMBIA

Pilot DPF retrofit project for public buses in Bogotá, Colombia

March 2013

Nestor Y. Rojas, Helmer R. Acevedo

Department of Chemical and Environmental Engineering

Universidad Nacional de Colombia, Bogota, Colombia.

Grupo de Investigación Calidad del Aire

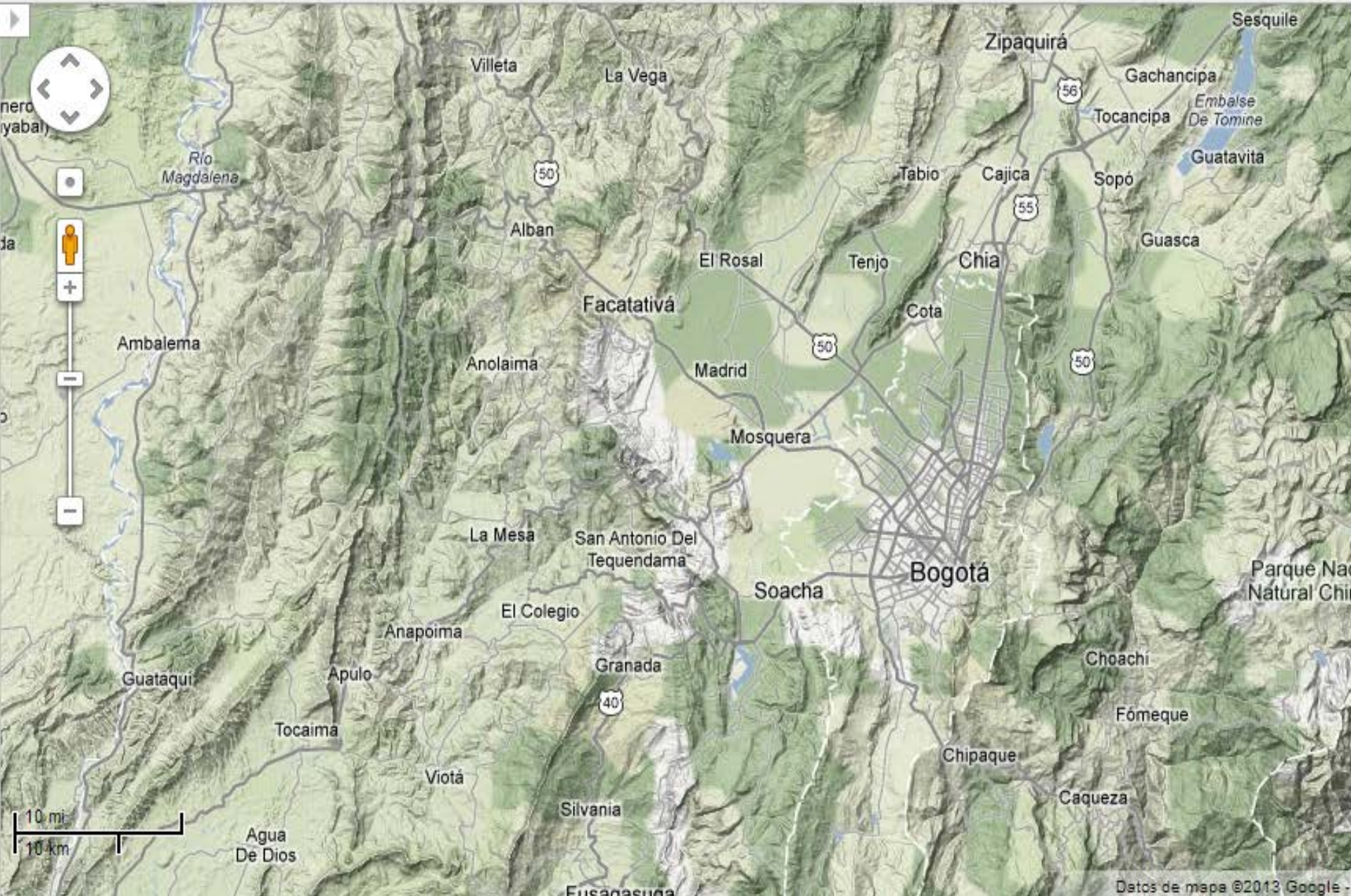

SCANIA
Marcopolo


UNIVERSIDAD NACIONAL DE COLOMBIA
SEDE BOGOTÁ
SECRETARÍA DISTRITAL DE AMBIENTE
BOGOTÁ
HUMANA
IDH-263
BUCARAMANGA

Overview

- >7.5 million inhabitants
- Altitude: 2,600 m
- Annual avg. T: 16ºC.
  - Max T: 24ºC
  - Min T: 0ºC

Google


Villeta
La Vega
Zipaquirá
Sesquile
Gachancipa
Tocancipa
Embalse De Tomine
Guatavita
Río Magdalena
Tabio
Cajica
Sopó
Guasca
Alban
El Rosal
Tenjo
Chia
Facatativá
Cota
Ambalema
Anolaima
Madrid
Mosquera
La Mesa
San Antonio Del Tequendama
Bogotá
Soacha
Parque Natural Chi
El Colegio
Anapoima
Granada
Choachi
Guataquí
Apulo
Fómeque
Tocaima
Chipaque
Viotá
Caqueza
Silvania
Agua De Dios
50
56
55
40
10 mi
10 km
Datos de mapa ©2013 Google

Air pollution

- Annual avg. PM10: 60 µg/m3
- In western areas: 90 µg/m3
- Frequent short thermal inversions

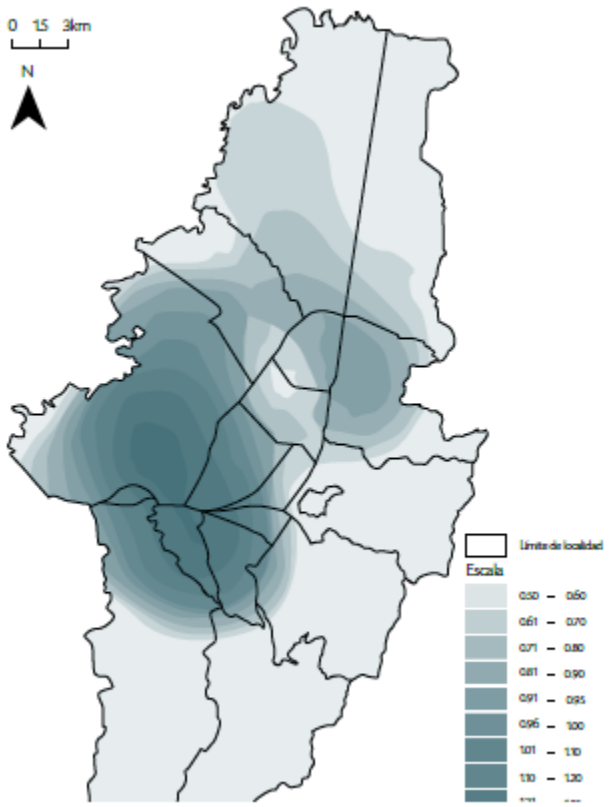


Foto tomada el 20 de abril de 2006 a las 8:30 a.m. (smog fotoquímico)

Foto: Juan Felipe Franco

Foto tomada el 3 de mayo de 2006 (segundo día para de transporte). 8:30 a.m.

Foto: Juan Felipe Franco

Transportation

- No metro system (!)
- BRT system progressive expansion since 2000
  - Today: 1300 articulated, 10 bi-articulated, 500 feeders
  - 1.5 million trips/day
- «Traditional» system based on small buses
  - 15,000 buses
- Fuel
  - 50 ppm S
  - High aromatic content
  - 5-10% Palm oil biodiesel

Current change in the system

- Segregated system

- Integrated system (SITP)

- Single card system for the whole city
- Reduction in the total number of buses
  - Scrap old buses
  - Reorganize routes and driving habits

SITP

- «Troncal» service
  - 1300 articulated and bi-articulated buses
  - 500 feeders
  - Mostly Euro II, Euro III engines (5-10 years of use)
  - Some Euro IV and Euro V engines (1 year of use)

- «Zonal» service
  - 11,100 vehicles with different capacities (80, 50, 40 and 19 passengers)
  - Mostly pre-Euro, Euro I and Euro II engines
  - Mostly 1-5 years of use

DPF retrofit project

- DPFs urgently needed
- Political will exists now
- Pilot program proposed: 14 buses, 4 categories
- 8 months

- Support needed:
  - Experience from Switzerland and Chile
  - Expertise, technology transfer, particle number instruments
  - DPFs manufacturer's involvement

Buses for the pilot project

- TM articulated (4) buses and feeders(2)
  - Mercedes
  - Volvo
  - Scania
- Mostly Euro I, II, some Euro IV, V

- Other buses (8)
  - Mainly Chevrolet
  - Other brands (VW, Agrale, Chinese brands)
- Mostly Euro I, Euro II

Pilot Project 2014

Secretaria Distrital de Ambiente &
Universidad Nacional de Colombia

2013 - 2014

ALCALDÍA MAYOR DE BOGOTÁ D.C.
SECRETARÍA DE AMBIENTE

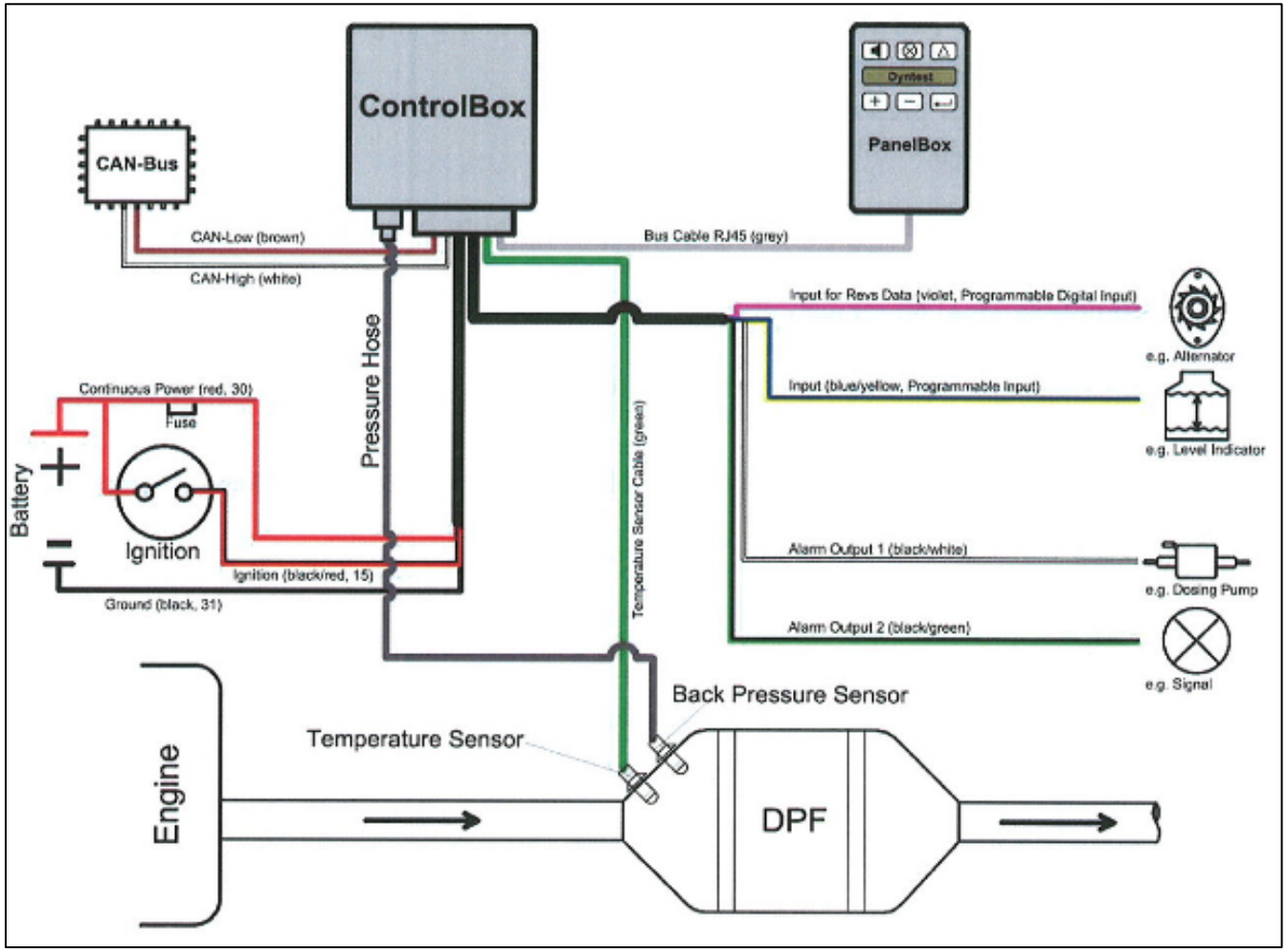
SCE para para vehículos del SITP de Bogotá

SISTEMAS DE RECOLECCION DE DATOS DE PRESION Y TEMPERATURA Y RESULTADOS VEHICULOS CON DPF´s

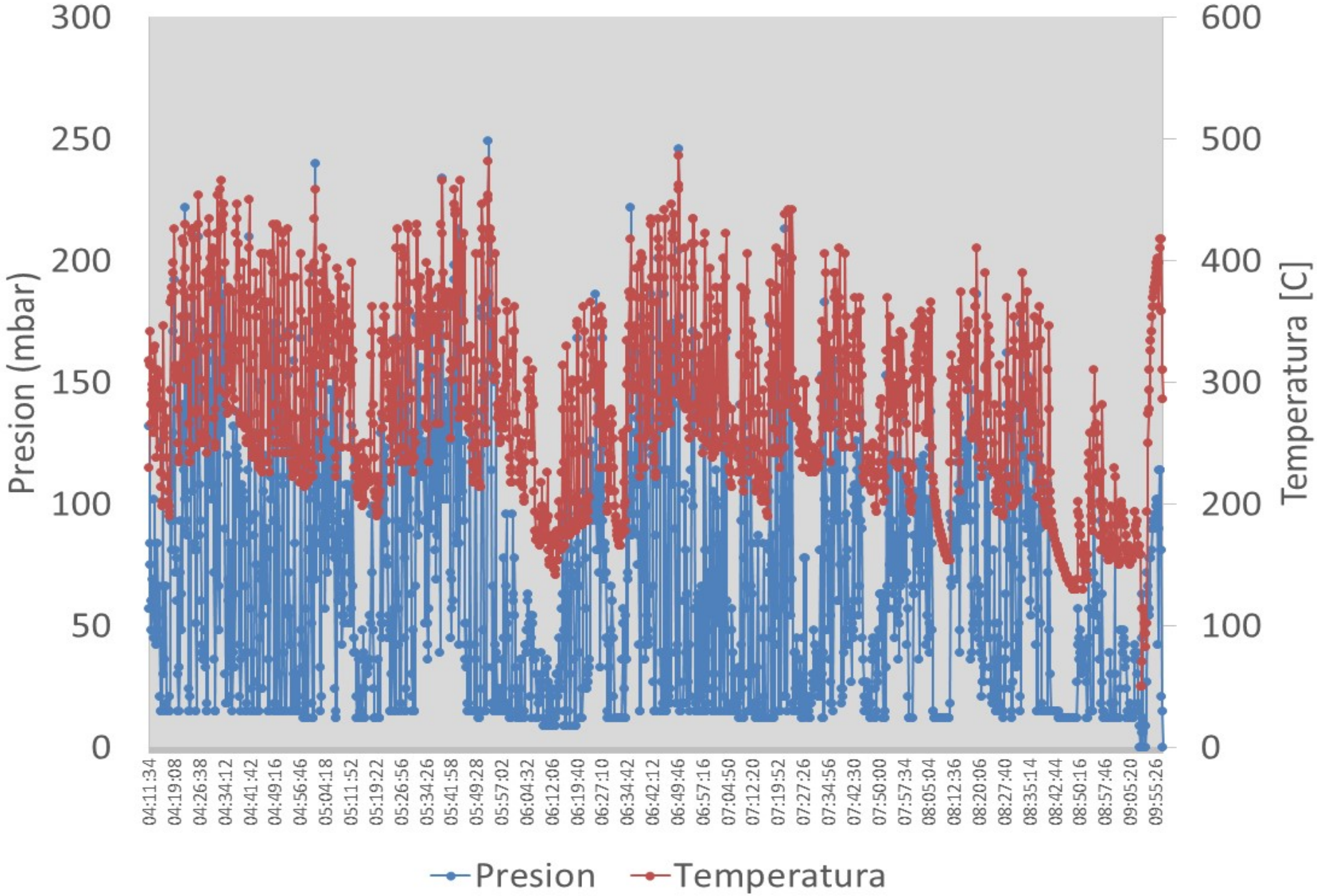
Helmer Acevedo Ph.D.

Bogotá D.C., Diciembre de 2014

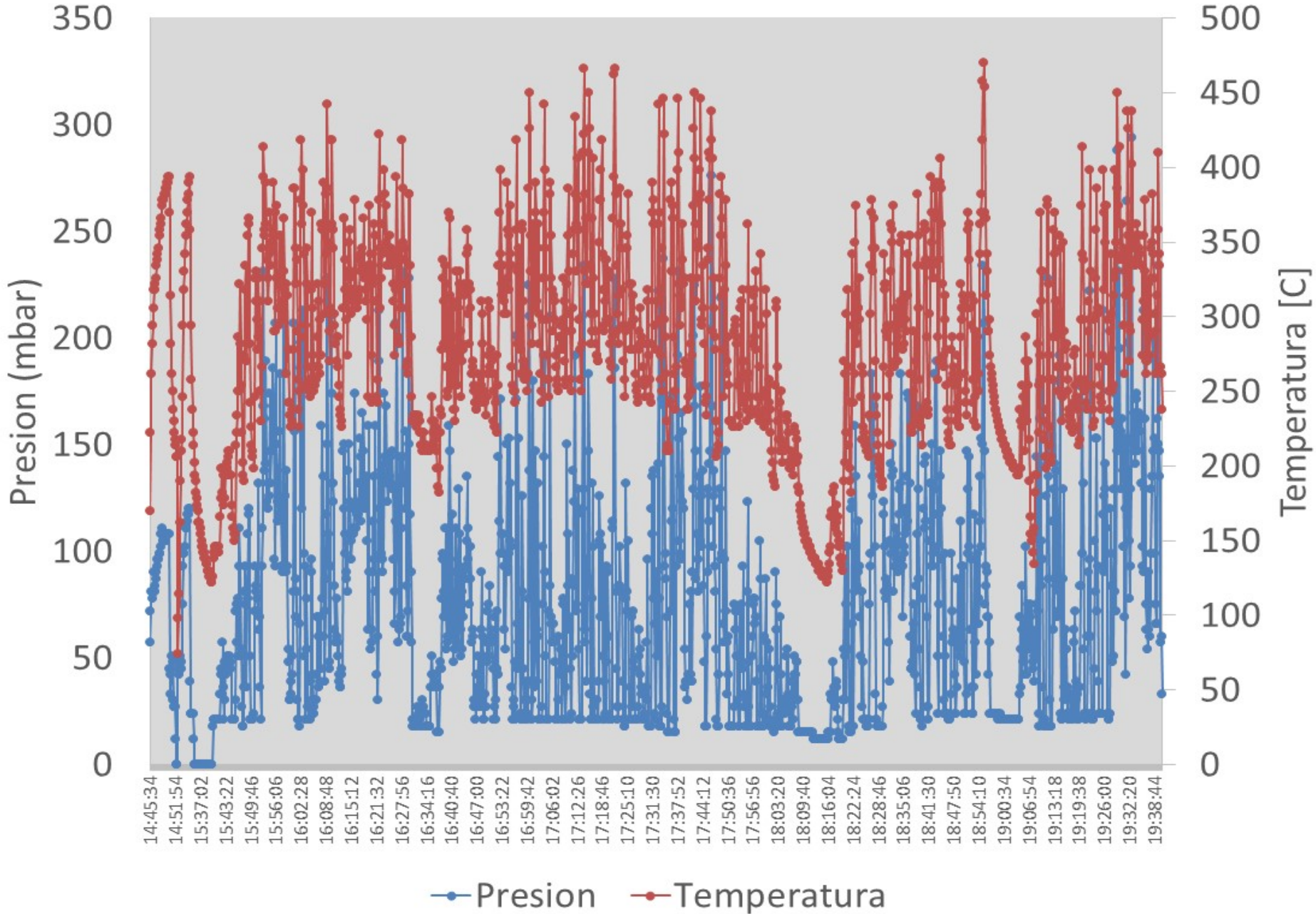
ELEMENTOS DE UN SISTEMA DATALOGGER



DATOS REGISTRADOS DURANTE OPERACION (21-11-2014)



DATOS REGISTRADOS DURANTE OPERACION (21-11-2014)



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Climate and Clean Air in Latin American Cities (CALAC)

Bogotá DPF Project

PRE DATALOGGING MEASUREMENTS WITHOUT DPF									PILOT FLEET BUS N° 3
General Data									
Vehicle Code:	K120		**Vehicle Plate:**	VEE 019			**Datalogger Serie N°:**		1438
Engine Specifications									
Brand:	Mercedes Benz		**Model:**	OM 457 LA			**Size [c.c.]:**		11967
			Manufacturer Data Sheet:		**Measurement:**		**Comments:**		
Max. Power [kW]@[rpm]:			265@2000		231@1690				
Max. Torque [Nm]@[rpm]:			1600@1100		1334@1690				
Max. speed [rpm]:			2250		2250				
Idle [rpm]:			560		560				
Measurement Conditions									
Ambient T° [°C]:	20,5		**Atm. Pressure [mbar]:**	760			**Rel. Humedity [%]:**		42,1

Load [%]	Pow. [kW]	Speed [rpm]	Exhaust T° [°C]	Exh. Press. [mbar]	Load [%]	Pow. [kW]	Speed [rpm]	Exhaust T° [°C]	Exh. Press. [mbar]
0%	0	1300+-30	*	2.413	50%	93		*	*
25%	47	1400+-100	192.4	4.964	75%	140		*	*

Idle Measurements			
Standstill Noise Max. rpm(1) [dBA]:	63.6	**Free Acceleration Op. [m^{-1}]:**	0.32

Dynamometer Measurements

Load	Actual Load [kW]	Opacity [m^{-1}]	NP [#/cm3]	CO [ppm]	THC [ppm]	NOx [ppm]	NO2 [ppm]
0%	30	0,12	**	130	310	653	34,6
25%	47	0,14	**	128	312	620,4	16,4
50%	93	0,30	**	178	292	928	2,8
75%	140	***	**				

Note (1): Sonometer position to 0,5 [m] distance of exhaust pipe exit through 45° regarding longitudinal axle.

PRE DATALOGGING MEASUREMENTS WITHOUT DPF									PILOT FLEET BUS N° 5
General Data									
Vehicle Code:	S157	**Vehicle Plate:**	VEE 166	**Datalogger Serie N°:**	1480				
Engine Specifications									
Brand:	SCANIA K310 / K94IA	**Model:**	DC9 21 310	**Size [c.c.]:**	9.000				
	Manufacturer Data Sheet:	**Measurement:**	**Comments:**						
Max. Power [kW]@[rpm]:	228 @ 1.900	148@1.285							
Max. Torque [Nm]@[rpm]:	1.550 @ 1.300	1.100@1.270							
Max. speed [rpm]:	2.200	2.200							
Idle[rpm]:	610	610							
Measurement Conditions									
Ambient T° [°C]:	19	**Atm. Pressure [mbar]:**	760	**Rel. Humidity [%]:**	51,5				
Load [%]	**Pow. [kW]**	**Speed [rpm]**	**Exhaust T° [°C]**	**Exh. Press. [mbar]**	**Load [%]**	**Pow. [kW]**	**Speed [rpm]**	**Exhaust T° [°C]**	**Exh. Press. [mbar]**
0%	0	1.350+-50	190,3	2,895	**50%**	74	1.306+-100	336	8,894
25%	37	*	*	*	**75%**	111	*	*	*
Idle Measurements									
Standstill Noise Max. rpm(1) [dBA]:	93,77	**Free Acceleration Op. [m^{-1}]:**	0,21						
Dynamometer Measurements									
Load	**Actual Load [kW]**	**Opacity [m^{-1}]**	**NP [#/cm3]**	**CO [ppm]**	**THC [ppm]**	**NOx [ppm]**	**NO2 [ppm]**		
0%	0	0,05	4,70E+06	97	*	838,4	12,4		
25%	37	*	*	*	*	*	*		
50%	74	0,41	4,51E+07	288	*	1265,7	4,7		
75%	111	*	*	*	*	*	*		

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Climate and Clean Air in Latin American Cities (CALAC)

Bogotá DPF Project

PRE DATALOGGING MEASUREMENTS WITH DPF	PILOT FLEET BUS N° __

General Data

Vehicle Code:	K120	**Vehicle Plate:**	VEE019	**Datalogger Serie N°:**	
Emission Standard	Euro 3	**Bus operator company:**	Somos K	**Filter manufacturer:**	DINEX
Filter type:					

Engine Specifications

Brand:	Mercedes Benz	**Model:**	MB OH2836	**Size [c.c.]:**	11967
Year:	2006	**Mileage:**	697207	**Chassis:**	9BH38215468478875

Measurement Conditions

	Manufacturer Data Sheet:	**Measurement:**	**Comments:**
Max. Power [kW]@[rpm]:	265@2000	142 @ 1680	-
Max. Torque [Nm]@[rpm]:	1600Nm@1100	843 @ 1560	-
Max. speed [rpm]:	-	2145	-
Idle [rpm]:	-	540	-

Measurement Conditions

Ambient T° [°C]:	23.2	**Atm. Pressure [mbar]:**		**Rel. Humidity [%]:**	39

Dynamometer Measurements Downstream 1

Load [%]	Pow. [kW]	Speed [rpm]	T° Datalogger [°C]	Press. Datalogger [mbar]	Load [%]	Pow. [kW]	Speed [rpm]	T° Datalogger [°C]	Press. Datalogger [mbar]
0%	0	1300	293	103	**50%**	88	1300	415	199
25%	44	1300	392	117	**75%***	110 (131)	1400	528	250

Load	$PM_{2.5}$ (mg/cm³)	NP [#/cm3]	CO [%]	THC [ppm]	NOx [ppm]	NO2 [ppm]	CO2 [%]
0%	1.03E-3	2.54E4	0.02	8	91	-	5.2
25%	2.567E-2	4.5E4	0.02	4	364	-	8.5
50%	5.81E-2	2.2E4	0.01	0	732	-	10.4
75%	3.016E-1	2.9E4	0.01	6	632	-	10.2

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Climate and Clean Air in Latin American Cities (CALAC)

Bogotá DPF Project

PRE DATALOGGING MEASUREMENTS WITH DPF	PILOT FLEET BUS N° __

General Data

Vehicle Code:	S157	**Vehicle Plate:**	VEE166	**Datalogger Serie N°:**	
Emission Standard	Euro 3	**Bus operator company:**	Transmasivo	**Filter manufacturer:**	Baumot
Filter type:					

Engine Specifications

Brand:	Scania	**Model:**	K94	**Size [c.c.]:**	8870
Year:	2007	**Mileage:**	707601	**Chassis:**	9BS46X2A073588156

Measurement Conditions

	Manufacturer Data Sheet:	**Measurement:**	**Comments:**
Max. Power [kW]@[rpm]:	210	128 @ 1270	148@1300 Pre DPF
Max. Torque [Nm]@[rpm]:	-	974 @ 1245	1099@1100 Pre DPF
Max. speed [rpm]:	-	2300	
Idle [rpm]:	-	500	

Measurement Conditions

Ambient T° [°C]:	21.7	**Atm. Pressure [mbar]:**		**Rel. Humedity [%]:**	42.3

Dynamometer Measurements Downstream 1

Load [%]	Pow. [kW]	Speed [rpm]	T° Datalogger [°C]	Press. Datalogger [mbar]	Load [%]	Pow. [kW]	Speed [rpm]	T° Datalogger [°C]	Press. Datalogger [mbar]
0%	0	1300	228	18	50%	74	1160	412	33
25%	37	1360	404	39	75%	111	1210	440	57

Load	$PM_{2.5}$ (mg/cm³)	NP [#/cm3]	CO [%]	THC [ppm]	NOx [ppm]	NO2 [ppm]	CO2 [%]
0%	5.98E-3	8.7E5	0.01	5.8	-	-	5.8
25%	2.15E-3	8.3E4	0.01	5.5	-	-	5.5
50%	1.07E-4	8.63E3	0.01	8.8	-	-	8.8
75%	4.8E-4	3.1E3	0.01	8.7	-	-	8.7

COMENTARIOS FINALES

- Es fundamental reducir los tiempos de ralentí de los vehículos para garantizar una regeneración adecuada
- ACEITES LUBRICANTES con bajo contenido de cenizas es una garantía para la vida útil del filtro
- Los filtros evaluados bajo condiciones de dinamómetro reducen en mas del 98% el número de partículas

District Secretariat of Environment

Bogota´s Diesel Particulate Filters Program

BDPF

Isabel Molina, Secretria del ambiente, Bogotá D.C.,

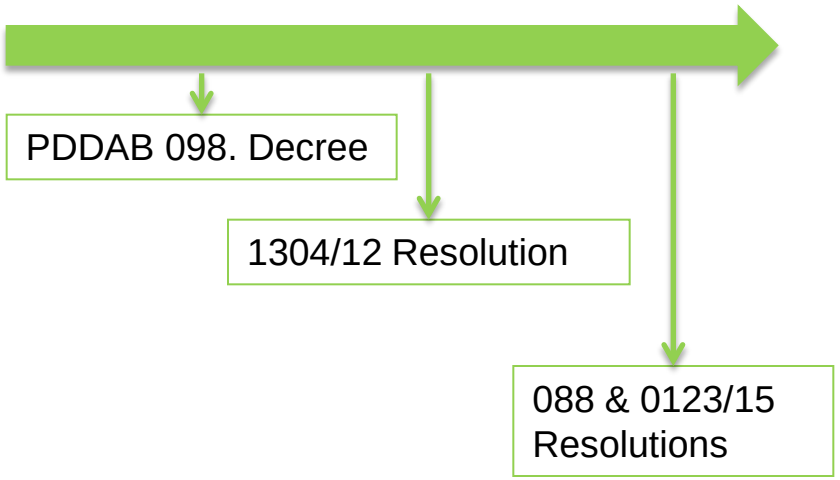
March 2015

Pilot Test officially terminated

Program

- Description
  - Local approval
  - Technical guidelines
    - Application Scope
    - Graduality
    - Emission levels
- Implementation
- Monitoring and control
- Lessons learned
- Bogota as Latin-American example

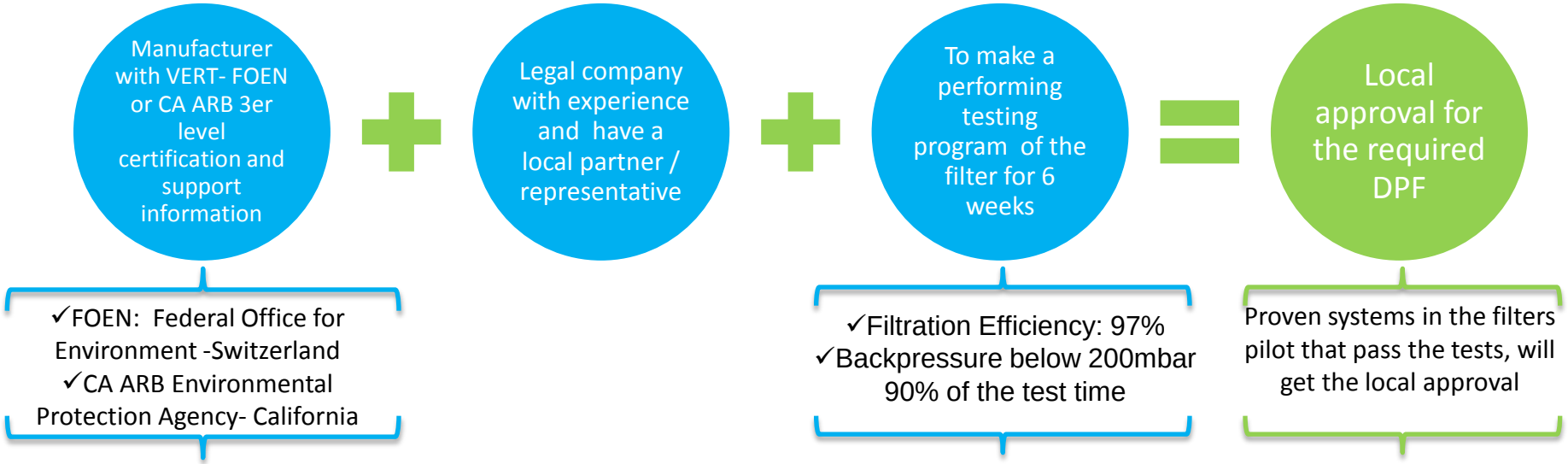
Schedule



Filters Local Approval

Next Steps

The local approval is granted to the local manufacturer/ representative of the technology that has successfully met the defined requirements by the SDA:



Approved systems will be publish on the **DPF systems approved list by the SDA** for use in Bogotá.

Application Scope

Technical Guidelines

The SITP operators in its *troncal* and *zonal* components, must install Diesel Particulate Filters to:

1. **All TRONCAL Buses which in December 31st of 2014 have crossed one million fifty thousand (1.050.000) kilometers or less.**

3. **All ZONAL Buses** that **are model year 2009 or higher**

Vehicles categorized as mini bus type are excepted for the fulfillment of the current program.

Graduality

Technical Guidelines

Each operator must set the overhaul fleet size (retrofit) with DPF, according to the conditions laid down in the application scope and install the filters according to their retrofit overhaul fleet size:

Tamaño de la flota objeto de retrofit. (Cantidad de vehículos)	Componente	Plazos						
		30-sep-15	31-dic-15	31-mar-16	30-jun-16	30-sep-16	31-dic-16	31-mar-17
≤90	Troncal	100%						
Entre 91 y 180	Troncal	40%	80%	100%				
>180	Troncal	28%	56%	84%	100%			

Tamaño de la flota objeto de retrofit. (Cantidad de vehículos)	Componente	Plazos						
		30-sep-15	31-dic-15	31-mar-16	30-jun-16	30-sep-16	31-dic-16	31-mar-17
≤90	Zonal		15%	36%	100%			
Entre 91 y 180	Zonal		6%	16%	50%	85%	100%	
>180	Zonal		3%	8%	30%	53%	75%	100%

between 1.600 -2.000 buses

Emission Levels

Technical Guidelines

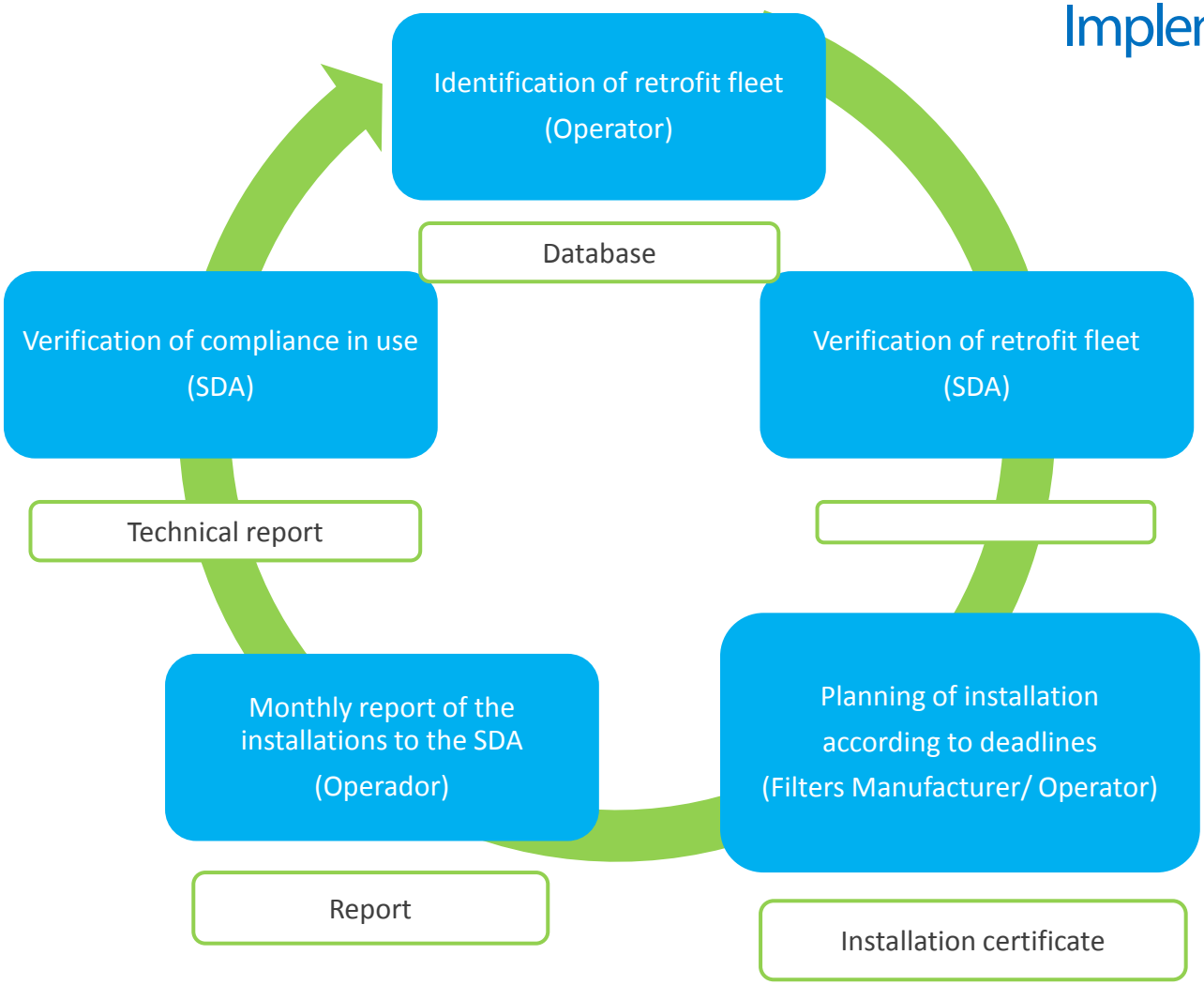
There are two CONTROL PARAMETERS limits to which the operator must comply:

1. Efficiency in the removal of number of ultra-fine particles (NP)
2. Opacity

Particulate number efficiency	97% Minimum	Concentration in (NP/cm3) before the filter against concentration (NP/cm3) after the filter.
Opacity limits	9,8 % Maximum Length to = 430 mm	Or equivalent value of K light extinction coefficient = 0.24m^{-1}

Next Steps

Implementation



Monitoring Mechanisms

Monitoring & Control

When Installing the Filter

Compliance in use

Manufacturer/supplier responsabilities

Instalation minutes, visual inspection, opacity before and after and filter effciency are checked.

Manufacturer loses approval

When the filter is in operation

Ramdom Control

Operator responsabilities

Document review, visual inspection, opacity limit compliance

Operator with penalty for non-compliance