Transports Metropolitans de Barcelona

CLEAN FLEETS

Innovation in BARCELONA CITY: TMB experience.

Barcelona, March 2014.

BARCELONA CLEAN CITY
TMB experience:

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Engineering and new development manager
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Israel Vallejo
Engineering Hybrid Systems and New Technologies
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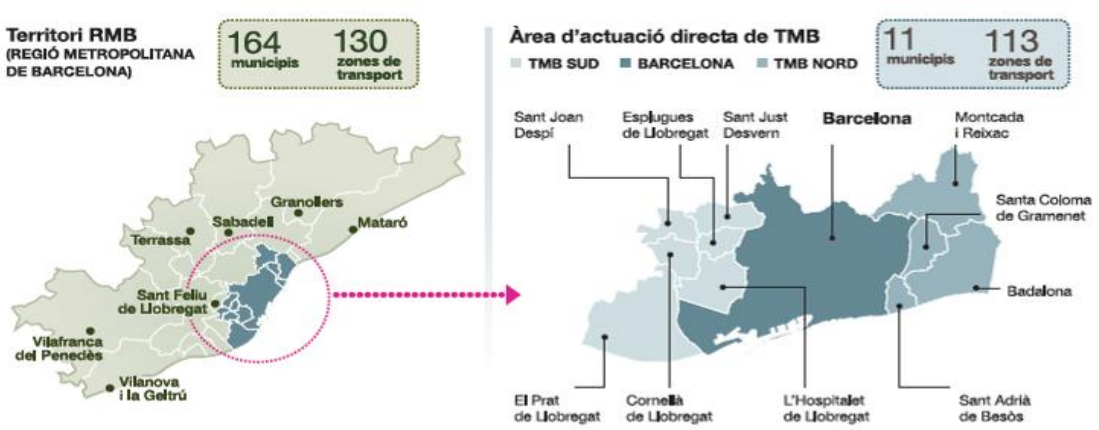
OVERVIEW

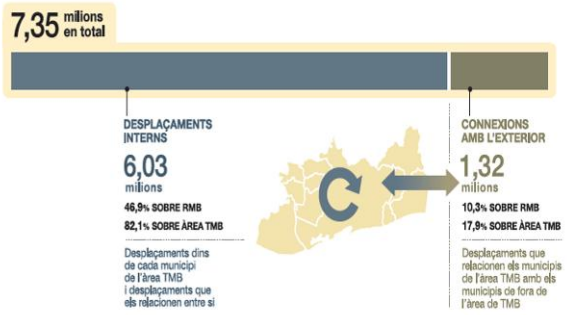
- Who is TMB?
- Why has TMB adapted to a clean fleet?
- How has TMB adapted to a clean fleet?
- New NETWORK in Barcelona
- Installation of Particles Filters.
- RETROFIT DIESEL Hybrid and CNG Hybrid.
- Acquisition of new clean buses.

BARCELONA METROPOLITAN AREA (AMB)

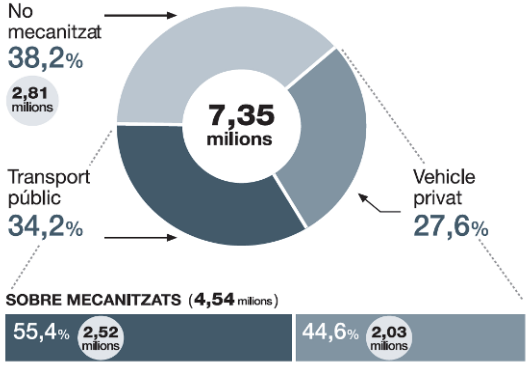


- **Number of Boroughs:** *11*
- **Surface area:** *333.4 Km²*
- **Population AMB:** *2.819.867*
- **Surface Barcelona Area:** *100.4Km².*
- **Population Barcelona City:** *1.611.822*

Barcelona Metropolitan Area



TMB bus moves around 380.000 passenger/day



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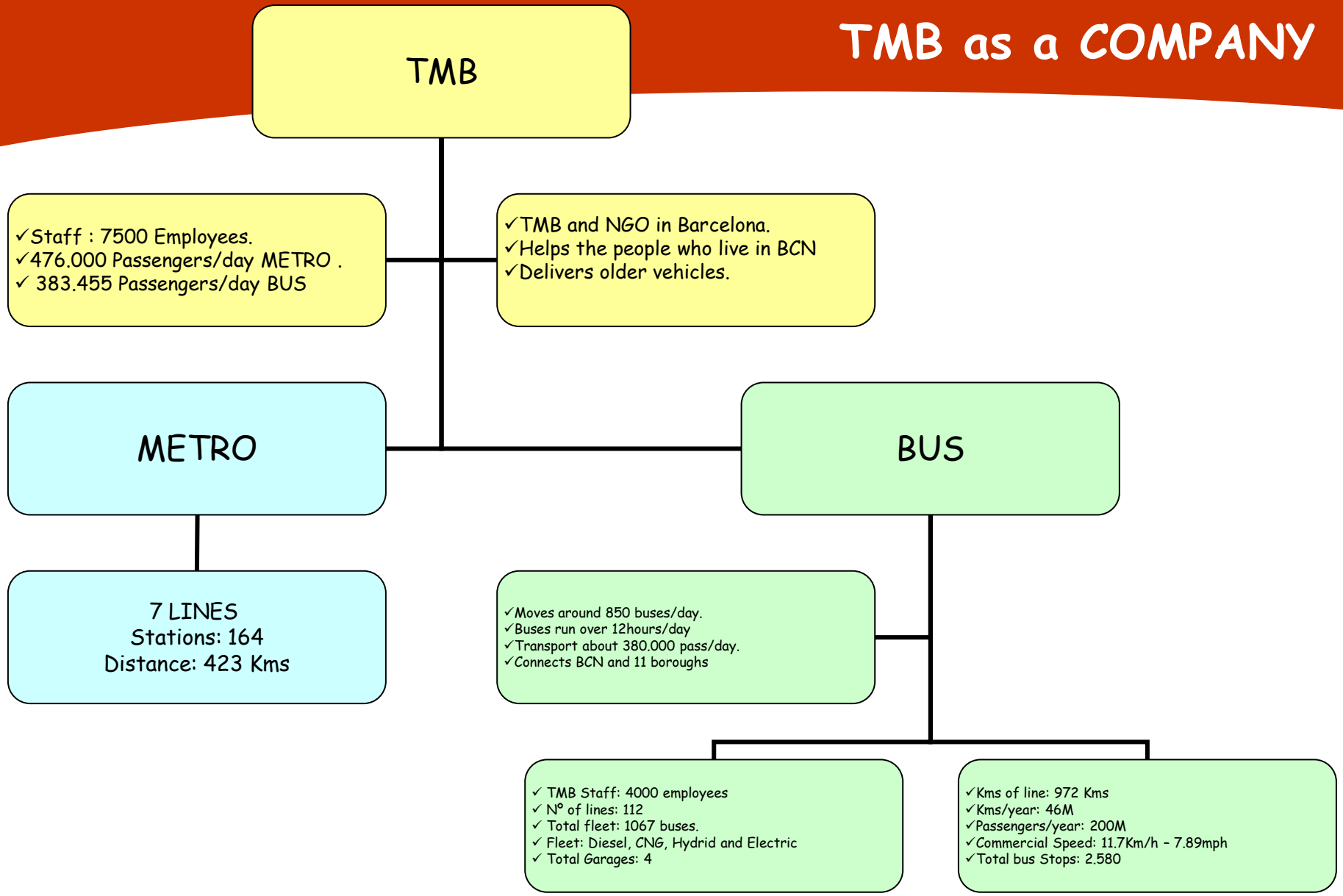
TMB as a COMPANY



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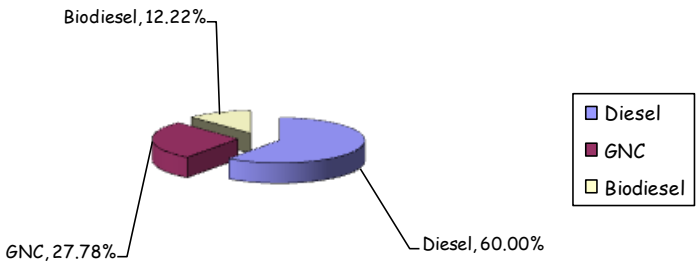
HUMAN RESOURCES AND ROLLING STOCK

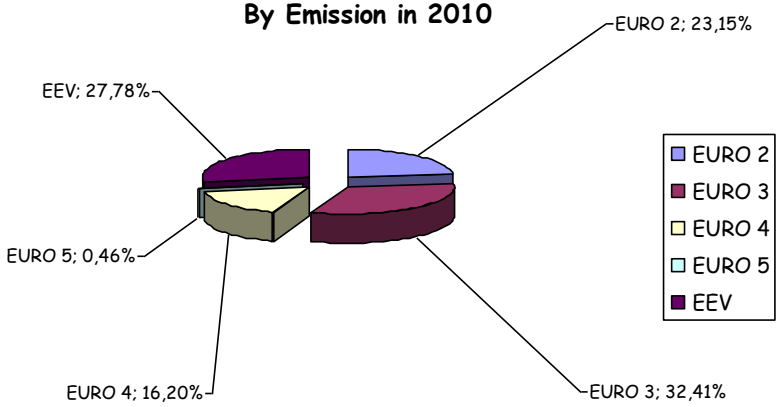
CHARACTERISTICS OF FLEET: 2010/2014

BUS FLEET in 2010 (1080 units)

By Fueling: Bus Fleet 2010 (1080 units)

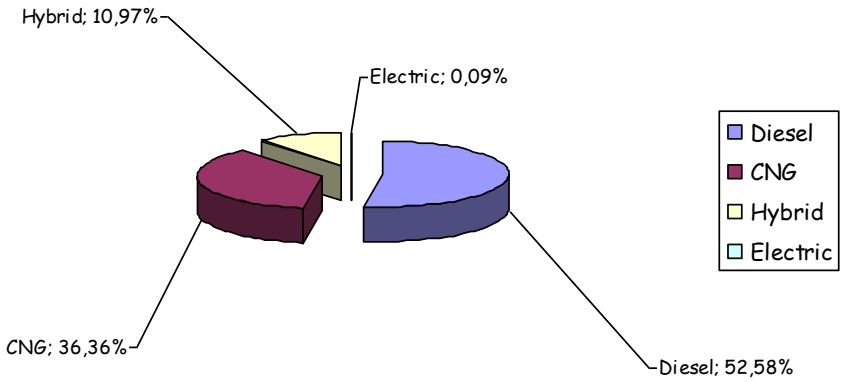


By Emission in 2010

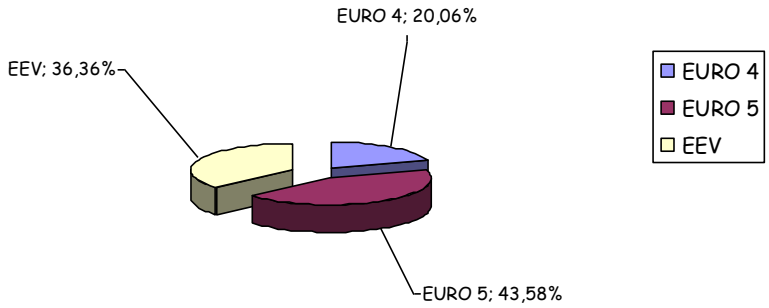


BUS FLEET in 2014 (1067 units)

By Fueling: Bus Fleet 2014 (1067 units)



By Emission in 2014



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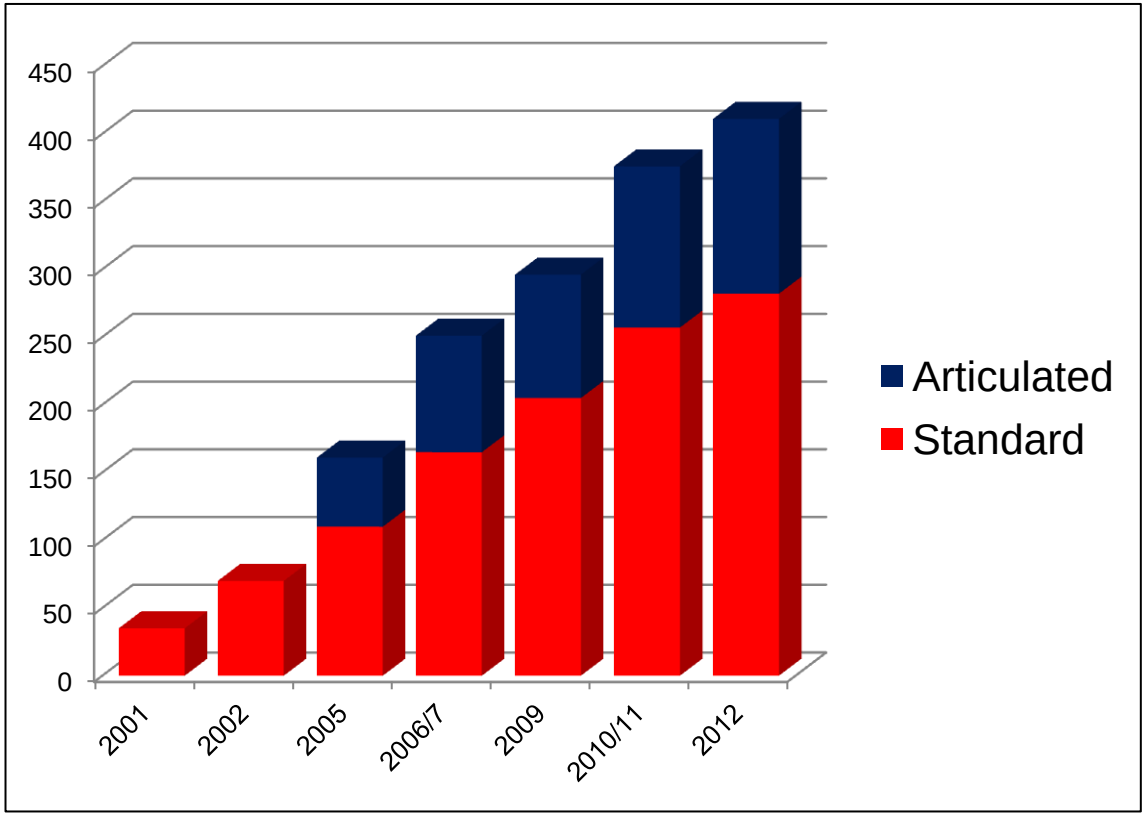
CNG Buses fleet

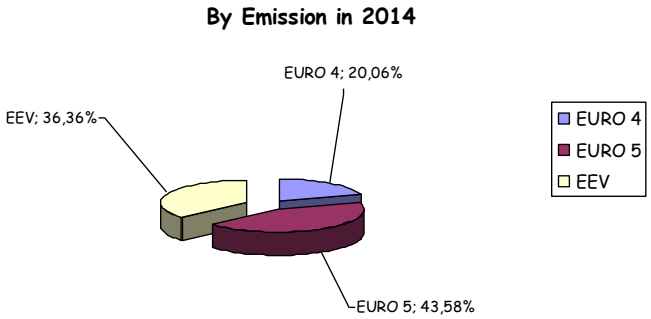
CNG Strategy: **411 buses (38%) in 2012, going to 500 buses in 2050**



To increase n ° of vehicles CNG up to 50 % of the total of the fleet for 2050

The main goal is to obtain with CNG Engines low emissions and more power.

Use a cheaper and less polluting fuel.



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Pollution in Barcelona Area

Study by Government of Catalonia 2007
Pollution Map over BCN

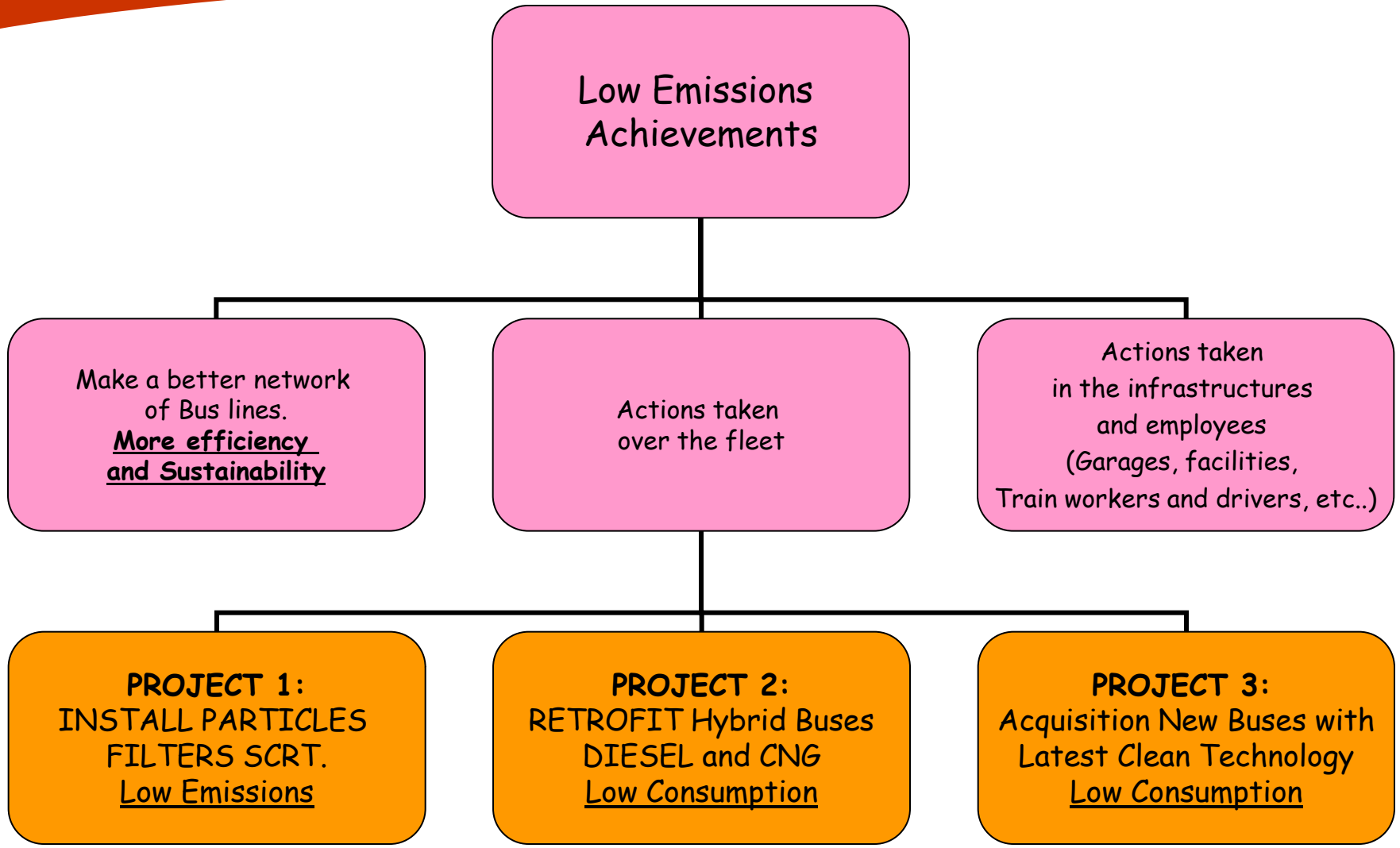
BLACK CLOUD
over
Barcelona City

First Decision was: REDUCE EMISSIONS

TMB has 1067 buses running all day in BCN and.....
WHAT COULD TMB DO
TO REDUCE THIS POLLUTION?

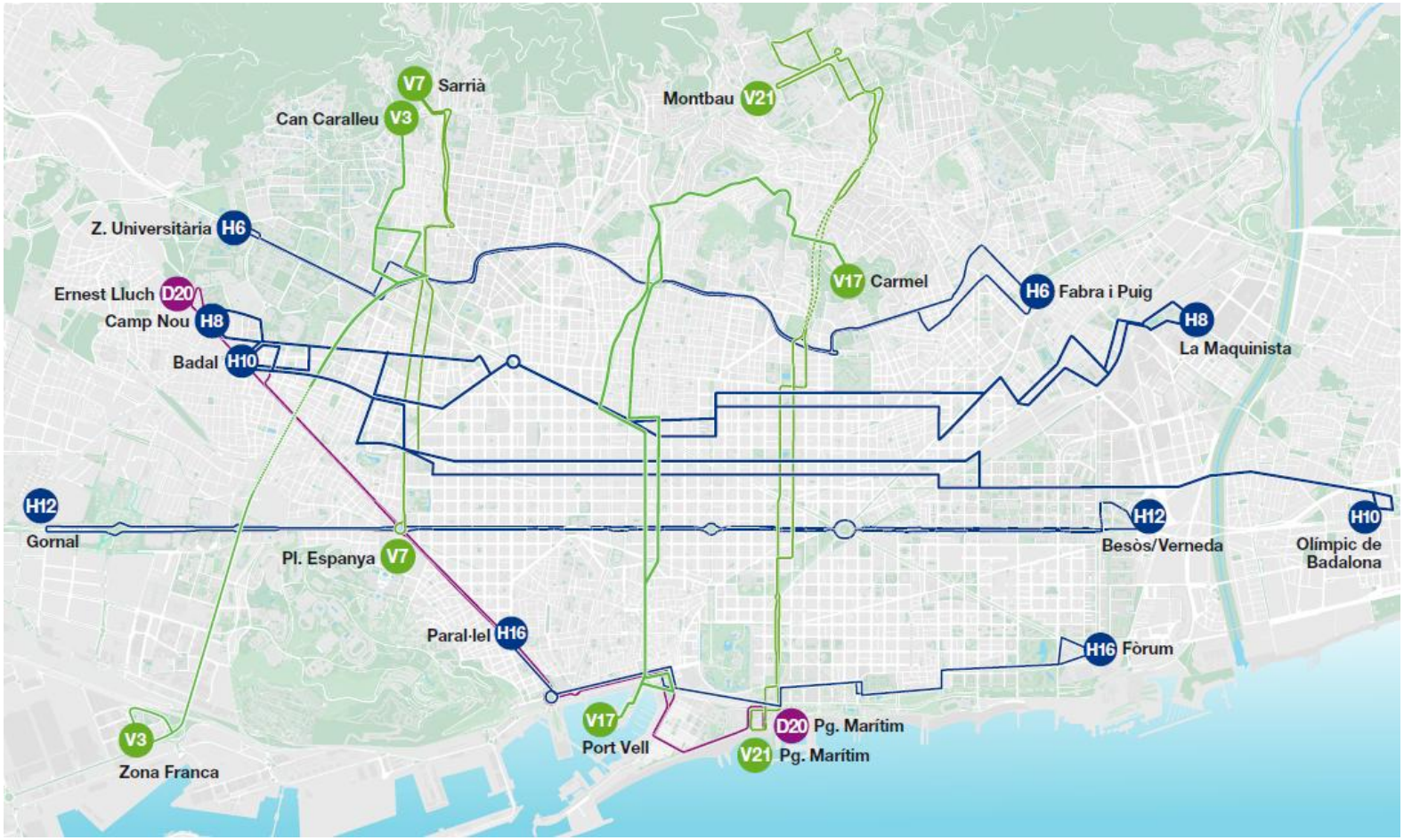
- New Network of bus Lines
- Adapt their old fleet to low emissions:
  Particle Filters and RETROFIT HYBRID
- Acquisition New Clean Fleet

How has TMB adapted to getting a clean fleet?



NOVA XARXA: NEW NETWORK IN BARCELONA

High level of service: faster and more efficient.



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PROJECT 1:
Install PARTICLES FILTERS SCRT

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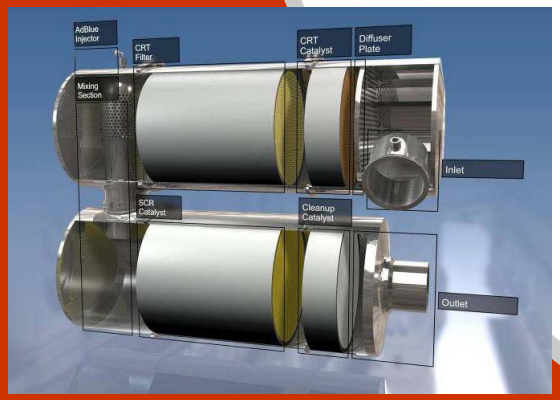


STEP 1: Estimated Calculations

Average Speed of test: 33Km/h
Units emissions: mg/Kms

Normative Emissions of the Engine DIESEL for the buses:

Standard	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
Oxidize of Nitrogen (NO_X)	-	-	500	250	180	80
Carbon Monixide (CO)	2720	1000	640	500	500	500
Hydrocarbons (HC)	-	-	-	-	-	-
HC + NO_X	970	900	560	300	230	170
Particles (PM)	140	100	50	25	5	5

Total Kms/year: 45000
Total Buses: 460

EMISSIONS	Without Particles Filter (EURO III) Tons/year/bus	With Particles Filters (EURO V) Tons/year/bus	Total Emissions Reduce with filters Tons/year /bus	% Reduce with filters bus/year	For 460 buses: Total Reduce emissions/year (Tons/year)
Oxidize of Nitrogen (NO_X)	22,5	8,1	14,4	64,00%	6.624
Carbon Monoxide (CO)	28,8	22,5	6,3	21,88%	2.898
HC (Hydrocarbons) + NO_X	25,2	10,35	14,85	58,93%	6.831
Particles (PM)	2,25	0,225	2,025	90,00%	932

STEP 2: PREVIOUS ANALYSES

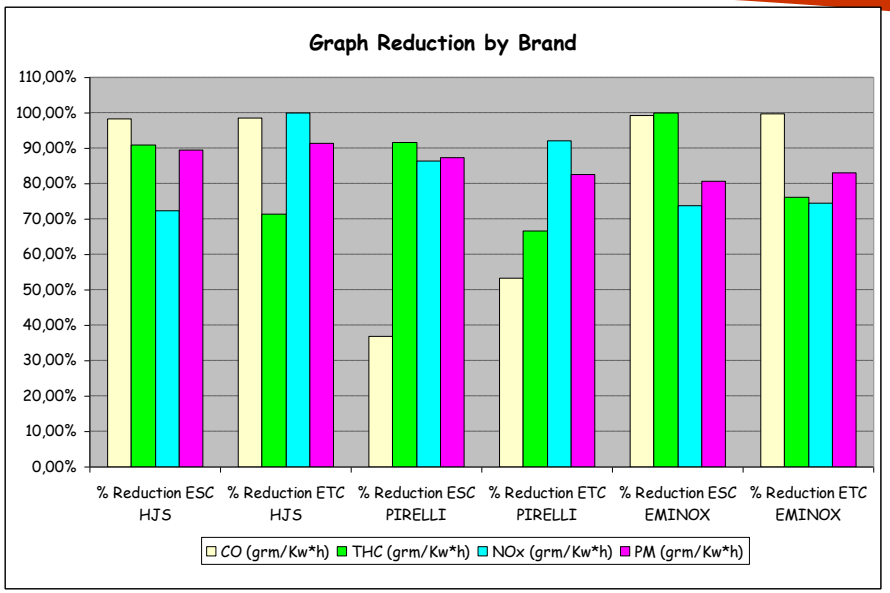
Search for companies who make filters: HJS, PIRELLI and EMINOX

Reduce the particles emissions and NOx between 50% and 60%

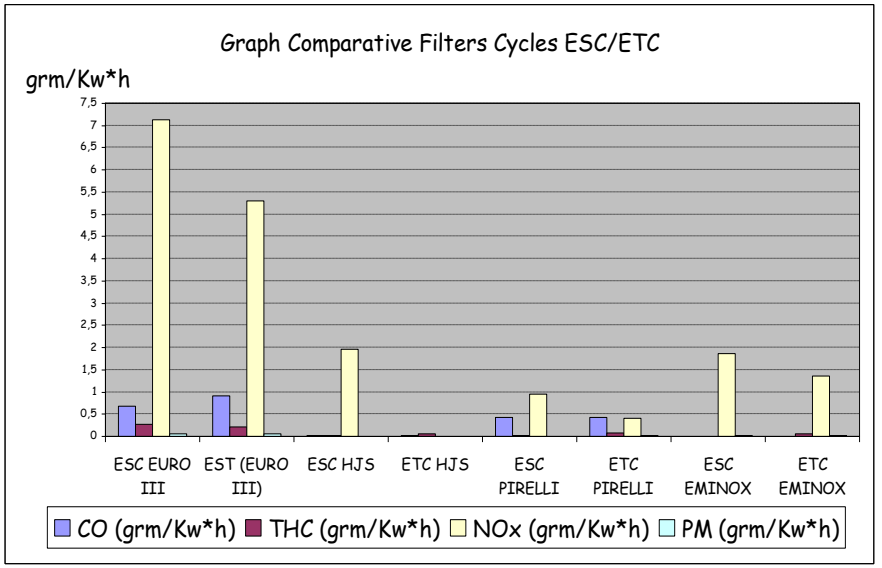
TESTING their TECHONOLOGY IN SPECIFIC LAB under ESC and ETC CHECK

Analysis of Results

CHOOSE THE BEST SOLUTION



TEST	CO (grm/Kw*h)	THC (grm/Kw*h)	NOx (grm/Kw*h)	PM (grm/Kw*h)
ESC EURO III	**0,6858**	**0,2794**	**7,1237**	**0,0596**
EST (EURO III)	**0,9103**	**0,2105**	**5,3114**	**0,06211**
ESC HJS	0,012108	0,025359	1,964275	0,006262
ETC HJS	0,012139	0,060309	0,005359	0,005359
% Reduction ESC HJS	98,23%	90,92%	72,43%	89,49%
% Reduction ETC HJS	98,67%	71,35%	99,90%	91,37%
ESC PIRELLI	0,4323	0,023603	0,961534	0,007566
ETC PIRELLI	0,42465	0,070291	0,4155	0,010818
% Reduction ESC PIRELLI	36,96%	91,55%	86,50%	87,31%
% Reduction ETC PIRELLI	53,35%	66,61%	92,18%	82,58%
ESC EMINOX	0,00547	0,0002	1,863207	0,011506
ETC EMINOX	0,002257	0,0500089	1,3579	0,010545
% Reduction ESC EMINOX	99,20%	99,93%	73,84%	80,69%
% Reduction ETC EMINOX	99,75%	76,24%	74,43%	83,02%



Take a Decision

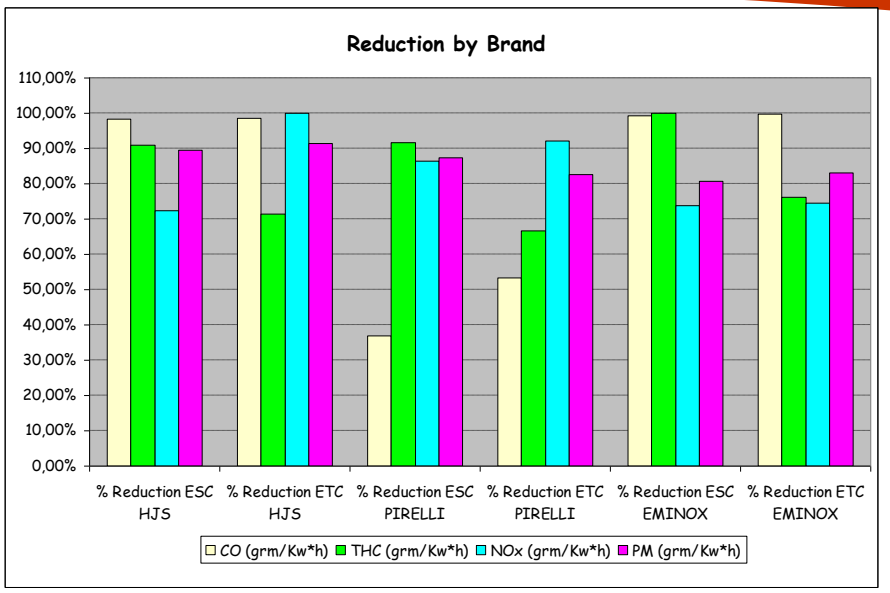
Search the companies who makes filters: HJS, PIRELLI and EMINOX

Reduce emissions the particles and NOx between 50% and 60%

TESTING their TECHONOLOGY IN ESPECIFIC LAB under ESC and ETC CHECK

Analysis of Results

CHOOSE THE BEST SOLUTION



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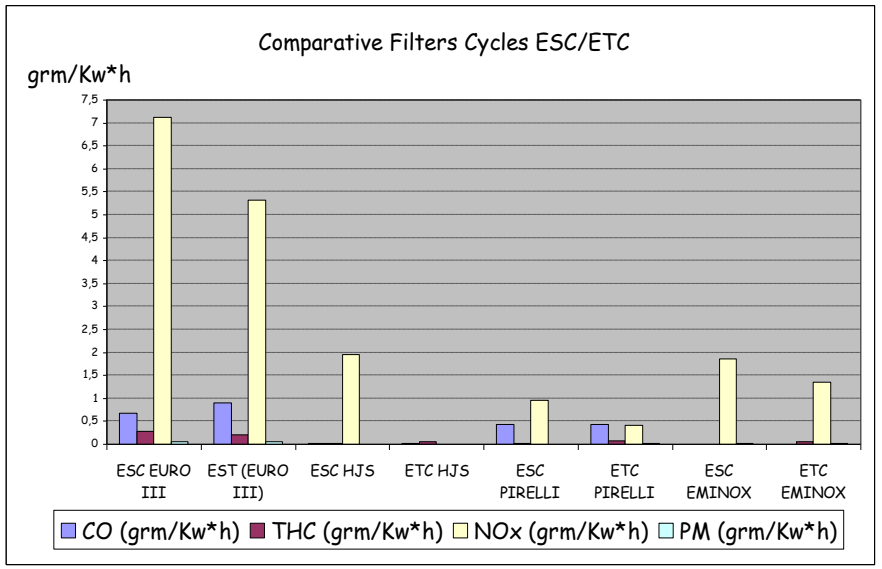

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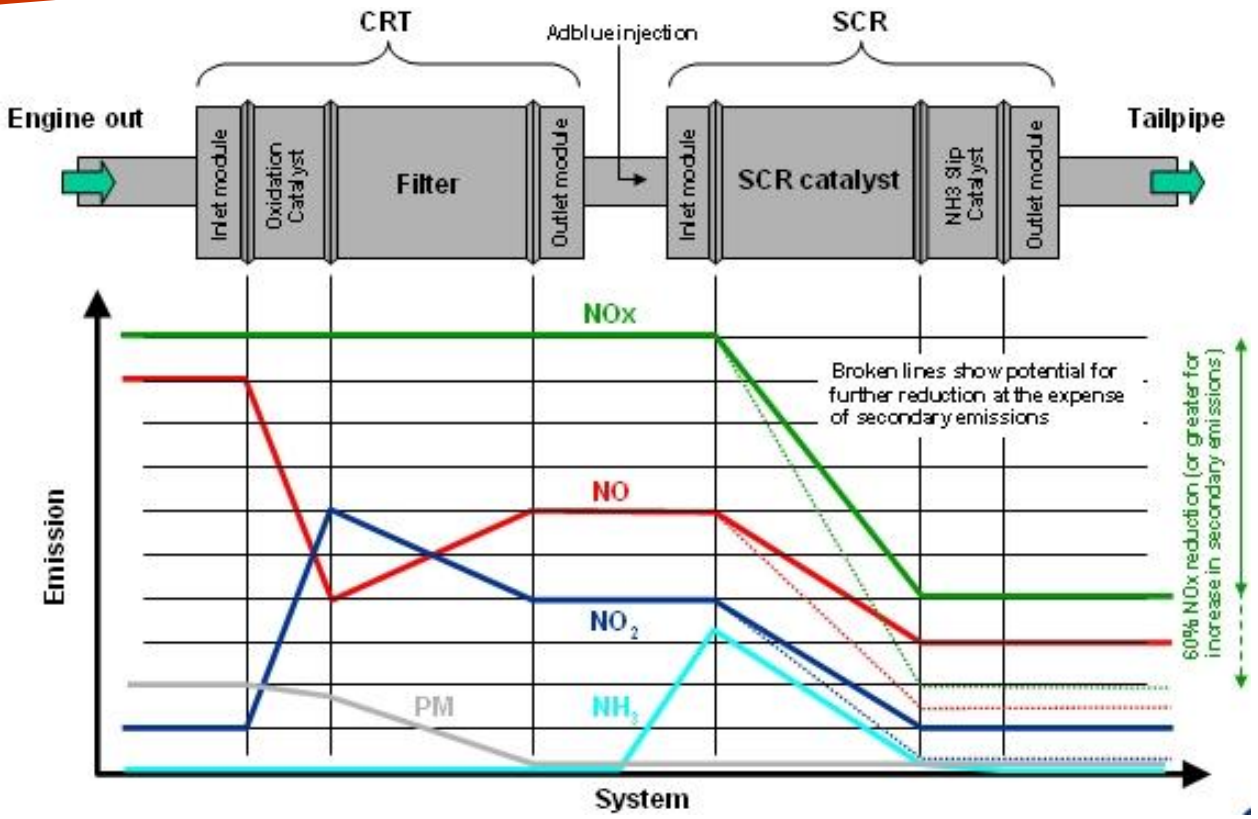
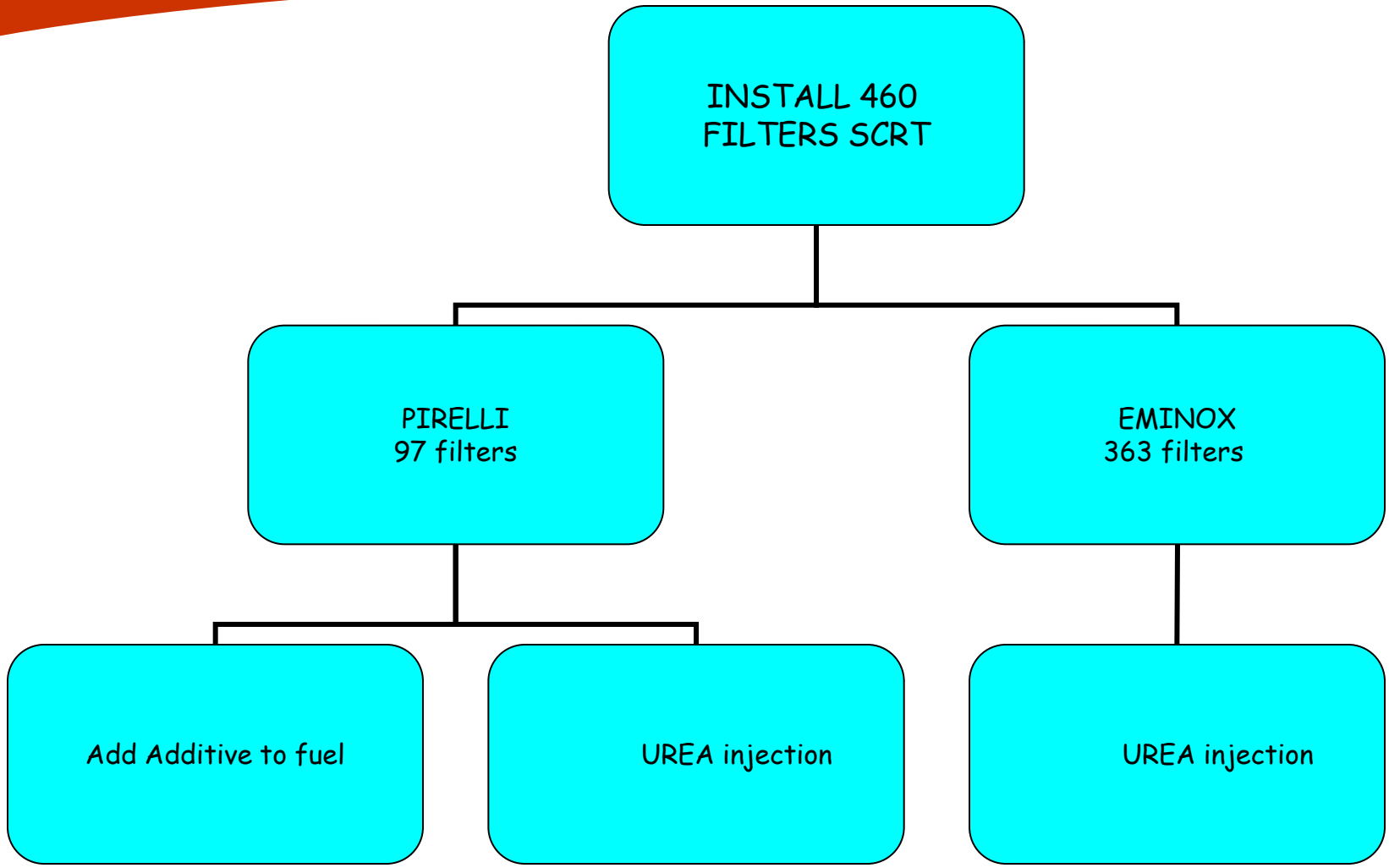
HOW DO THE FILTERS DO IT?



Treatment exhaust gases in three stages:

* Stage 1: CRT Reduce NO and PM. Red and grey line.
* Stage 2: Adblue injection (NH3). Light blue line.
* Stage 3: SCR Reduce NOx and NO_2. Green, red and blue line.

STEP 3: Install FILTERS SCRT

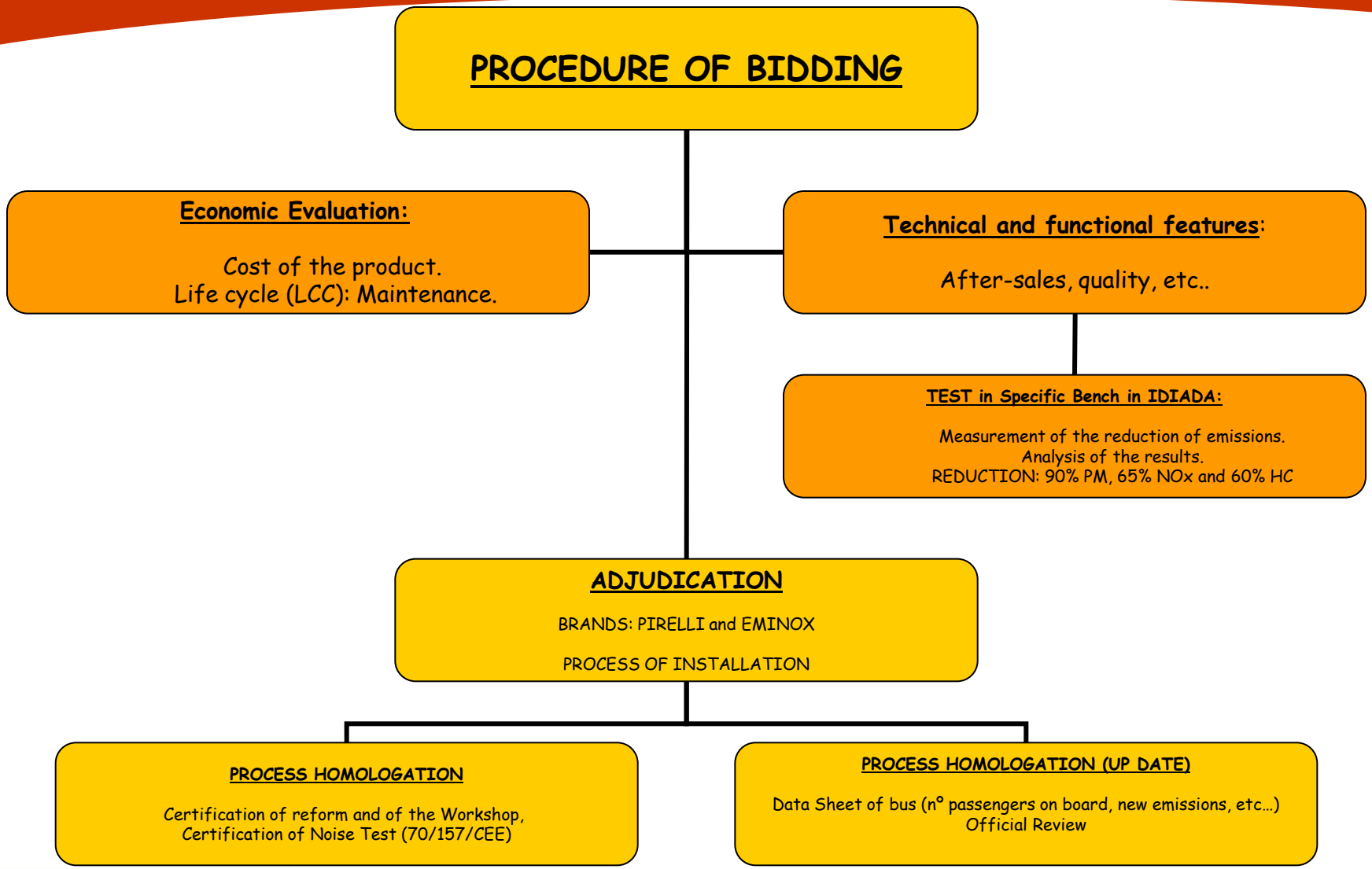


INSTALL ON BOARD SYSTEM SCRT

MAN

Mercedes

STEP 4: ADMINISTRATIVE



STEP 5: END RESULT

Total Kms/year: 45000
Total Buses: 460

EMISSIONS	Without Particles Filter (EURO III) Tons/year/bus	With Particles Filters (EURO V) Tons/year/bus	Total Emissions Reduce with filters Tons/year /bus	% Reduce with filters bus/year	For 460 buses: Total Reduce emissions/year (Tons/year)
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EMISSIONS	Without Particles Filter (EURO III) Tons/year/bus	With Particles Filters (EURO V) Tons/year/bus	Total Emissions Reduce with filters Tons/year /bus	% Reduce with filters	For 460 buses: Total Reduce emissions/year (Tons/year)
Oxidize of Nitrogen (NO_X)	22,5	2,25	20,25	90,00%	9.315
Carbon Monoxide (CO)	28,8	2,88	25,92	90,00%	11.923
HC (Hydrocarbons) + NO_X	25,2	6,3	18,9	75,00%	8.694
Particles (PM)	2,25	0,3375	1,9125	85,00%	880

PROJECT 2:
RETROFIT DIESEL and CNG

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70 Diesel HYBRID BUSES
12 CNG HYBRID BUSES

ACC1Ó
CIDEM | COPCA

Unió Europea
Fons Europeu de Desenvolupament Regional
"Una manera de fer Europa"

EXISTING FLEET: RETROFIT PROJECT BUSES TRANSFORM TO HYBRID

Transports Metropolitans de Barcelona

BRAND: IVECO DIESEL and CNG
Type: Standard 12m
Storage ENERGY: UCAP's
Technology: SIEMENS
Electric motor: 134 kW
Generator: 180 kW

70 RETROFITS DIESEL

Model: IVECO CITY-CLASS
Body builder: NOGE
Engine: IVECO Cursor.
Fuel: Diesel
Power: 245 CV
Environment standard: Euro III.

COLLABORATION TMB AND NATURAL GAS FENOSA

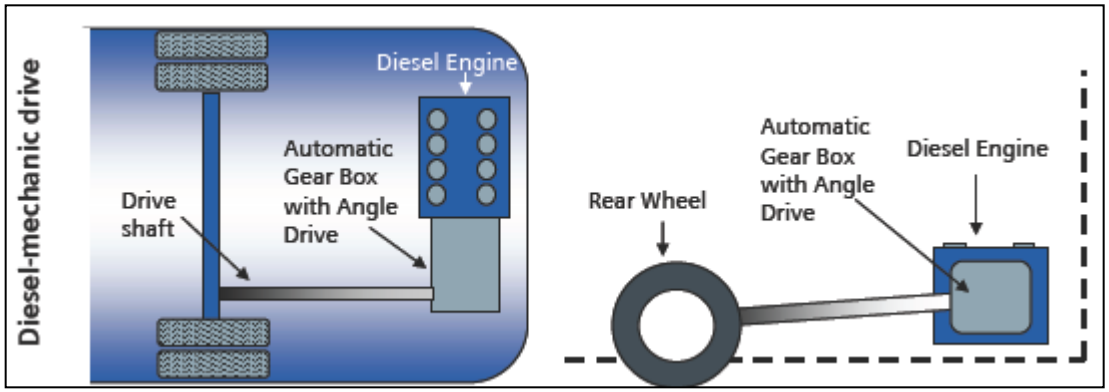
12 RETROFITS CNG

Model: IVECO CITY-CLASS GNC 491.12.27
Body builder: CASTROSUA
Engine: IVECO Cursor.
Fuel: CNG
Power: 270 CV
Environment standard: EEV

PROTOTYPE DIESEL and CNG

MEMBERS

Operator:	TMB
Hybrid technology:	SIEMENS
Body builder:	NOGE
Engineering:	EDAG



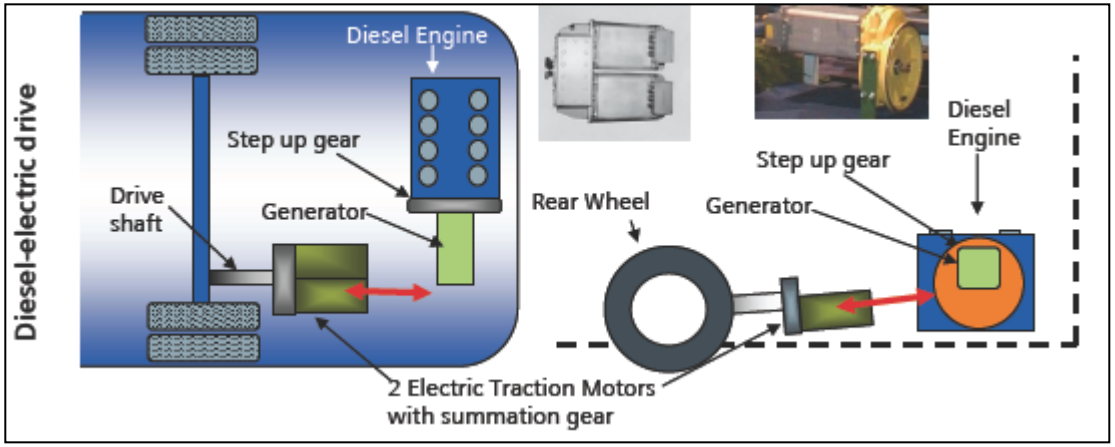
CHARACTERISTICS

SERIAL System

Storage system: U-caps

MODE: Stop and go

2 electric motors

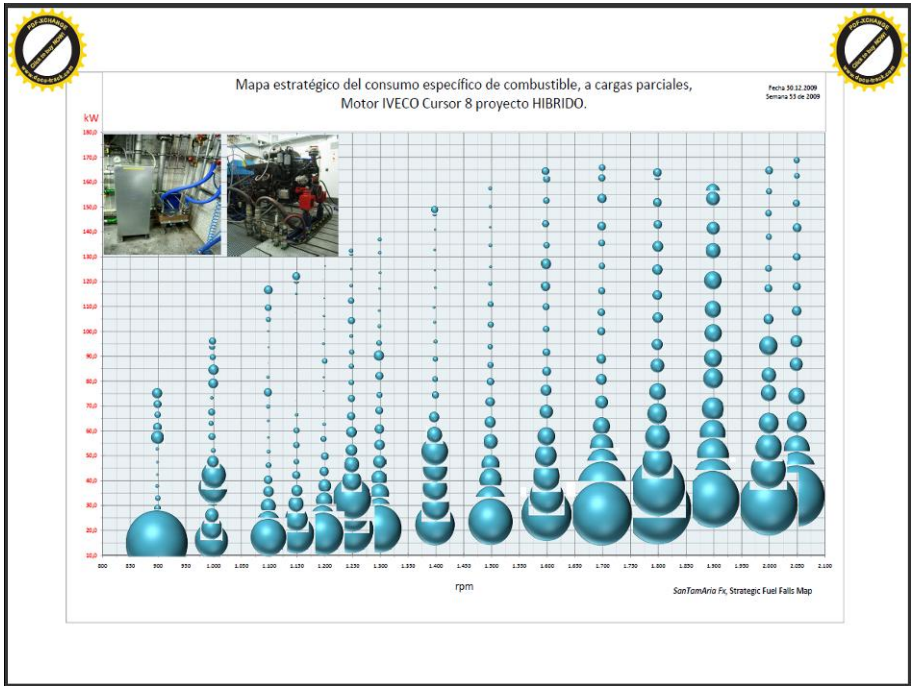


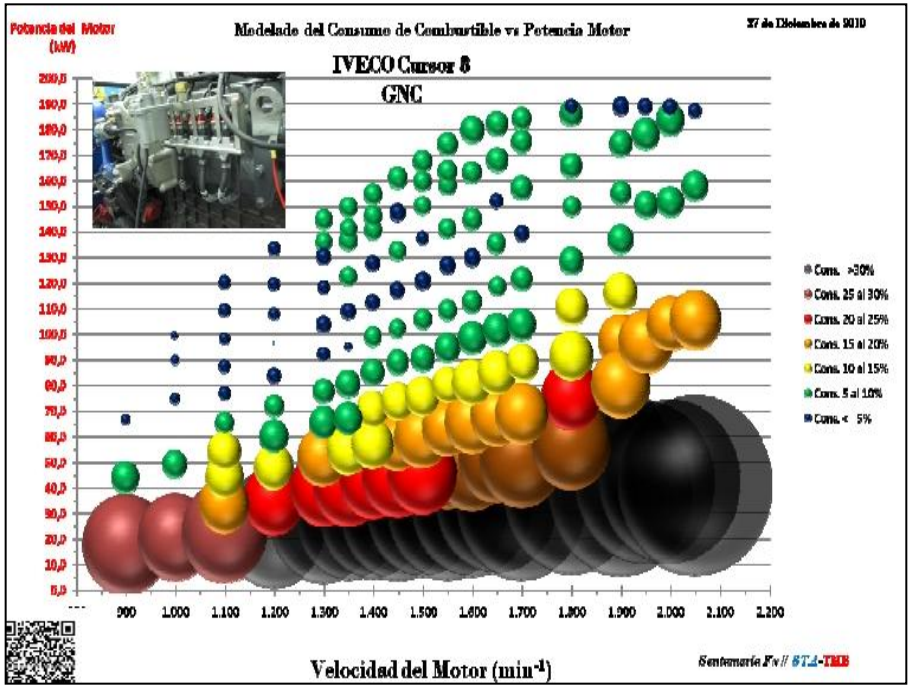
Search for the best point for running engine

Testing the Engine on a specific bench and search for the test point to work.

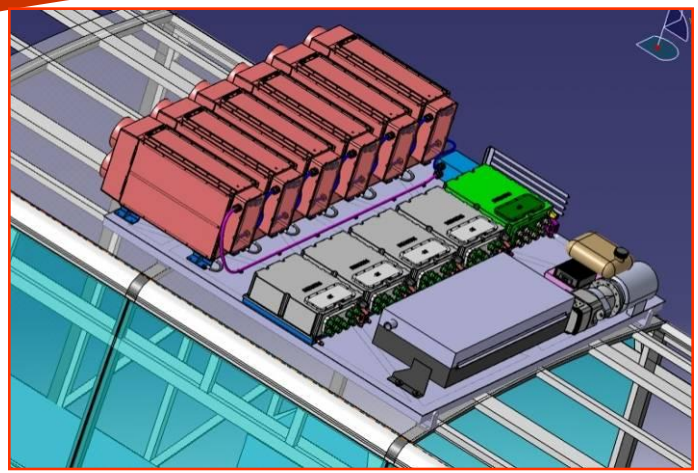
This point is in the smaller balls.

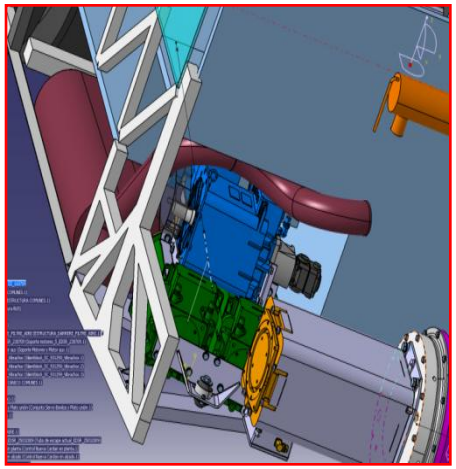
Gets low consumption of fuel.

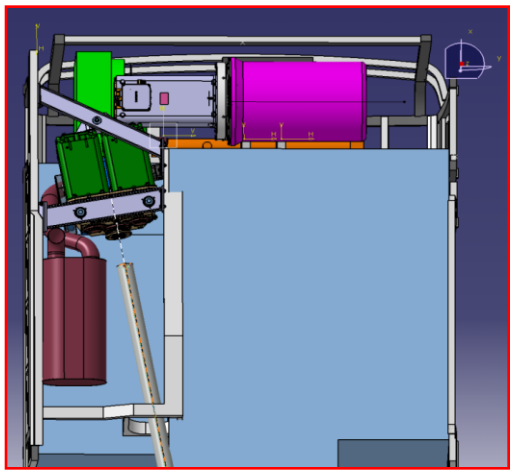


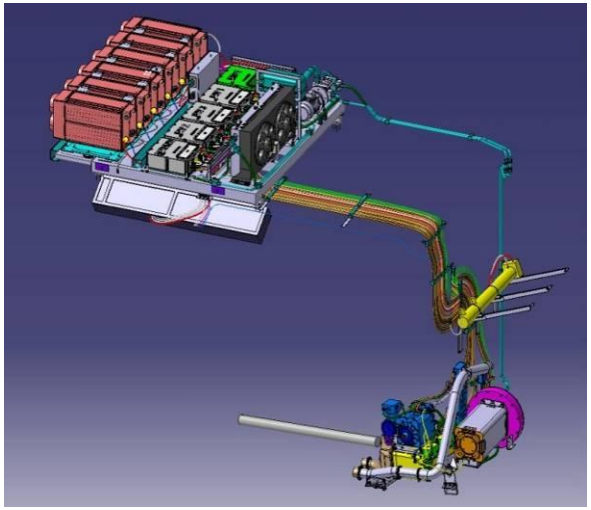


LAYOUT HYBRID TRANSFORMATION









ANALYSIS OF FEASIBILITY PROTOTYPE (LAB + BUS lines).

Recovery time:

- Fuel Savings: More than 20% (depending on the bus routes).

- In less than 10 years we will recuperate the investment.

Estimated Calculations and Recuperation time

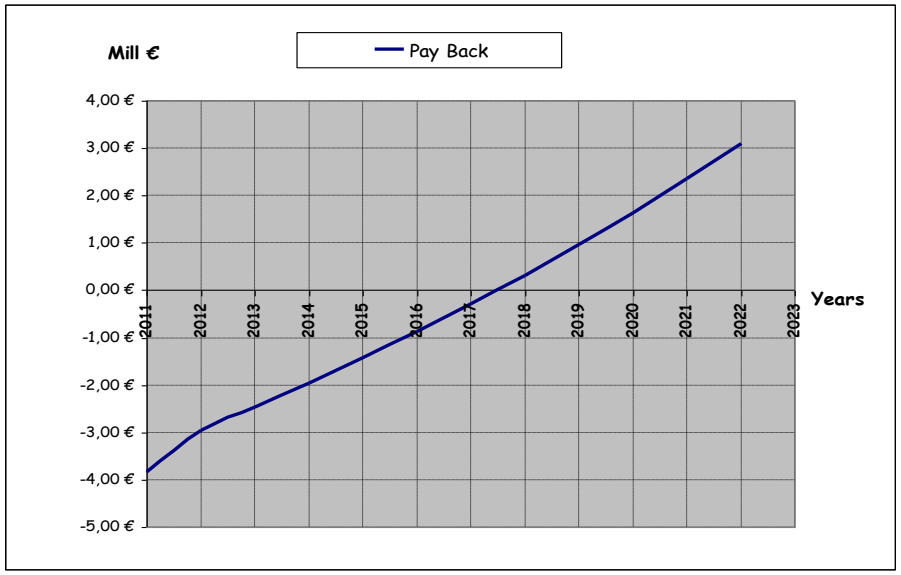
Average Consumption Initial Lit/100Kms: 60
% Saving Expected of RETROFIT: 20
Consumption RETROFIT Lit/100Kms: 48,00

Kms/year: 45000
Total fleet buses: 70
% Increase Expected price of fuel/year: 5

Year	Evolution Expected Fuel Price €/lit	Fuel Consumption NO RETROFIT Annual/Bus	Fuel Consumption RETROFIT Annual/Bus	Total Saving €/year/bus	Total fuel Consumption by 100 Buses NO RETROFIT	Total fuel Consumption by 100 Buses RETROFIT	Total Saving €/100buses/year	Accumulated Quantities	Pay Back Mill €
2011	1,1	29.700,00 €	29.700,00 €	0,00 €	2.079.000,00 €	2.079.000,00 €	0,00 €	0,00 €	-3,85 €
2012	1,16	31.185,00 €	24.948,00 €	6.237,00 €	2.182.950,00 €	1.746.360,00 €	436.590,00 €	436.590,00 €	-2,95 €
2013	1,21	32.744,25 €	26.195,40 €	6.548,85 €	2.292.097,50 €	1.833.678,00 €	458.419,50 €	895.009,50 €	-2,47 €
2014	1,27	34.381,46 €	27.505,17 €	6.876,29 €	2.406.702,38 €	1.925.361,90 €	481.340,48 €	1.376.349,98 €	-1,97 €
2015	1,34	36.100,54 €	28.880,43 €	7.220,11 €	2.527.037,49 €	2.021.630,00 €	505.407,50 €	1.881.757,47 €	-1,44 €
2016	1,40	37.905,56 €	30.324,45 €	7.581,11 €	2.653.389,37 €	2.122.711,49 €	530.677,87 €	2.412.435,35 €	-0,88 €
2017	1,47	39.800,84 €	31.840,67 €	7.960,17 €	2.786.058,84 €	2.228.847,07 €	557.211,77 €	2.969.647,11 €	-0,30 €
2018	1,55	41.790,88 €	33.432,71 €	8.358,18 €	2.925.361,78 €	2.340.289,42 €	585.072,36 €	3.554.719,47 €	0,32 €
2019	1,63	43.880,43 €	35.104,34 €	8.776,09 €	3.071.629,87 €	2.457.303,89 €	614.325,97 €	4.169.045,44 €	0,96 €
2020	1,71	46.074,45 €	36.859,56 €	9.214,89 €	3.225.211,36 €	2.580.169,09 €	645.042,27 €	4.814.087,72 €	1,64 €
2021	1,79	48.378,17 €	38.702,54 €	9.675,63 €	3.386.471,93 €	2.709.177,54 €	677.294,39 €	5.491.382,10 €	2,35 €
2022	1,88	50.797,08 €	40.637,66 €	10.159,42 €	3.555.795,53 €	2.844.636,42 €	711.159,11 €	6.202.541,21 €	3,10 €
2023	1,98	53.336,93 €	42.669,55 €	10.667,39 €	3.733.585,30 €	2.986.868,24 €	746.717,06 €	6.949.258,27 €	
					34.746.291,34 €	27.797.033,07 €	6.949.258,27 €		

% Increase Price Expected Between 2012 and 2023: 71,03%

Total cost/bus: 110.000,00 €
Total cost RETROFIT: 7.700.000,00 €
Goverment Helps/bus (50%): 55.000,00 €
Total cost TMB/bus: 55.000,00 €
Total cost TMB: 3.850.000,00 €



Transports Metropolitans de Barcelona

Estimated Calculations and Pay Back time

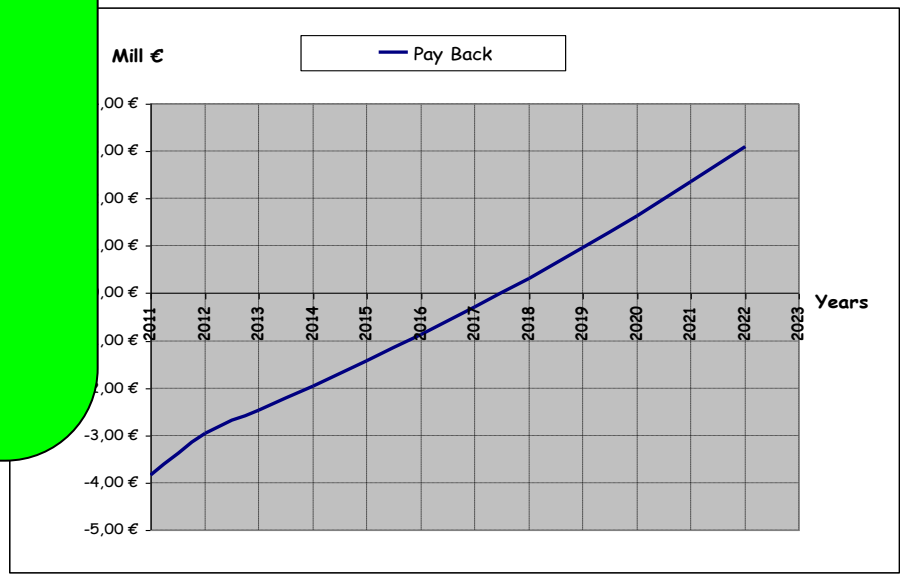
Average Consumption Initial Lit/100Kms: 60
% Saving Expected of RETROFIT: 20
Consumption RETROFIT Lit/100Kms: 48,00

Kms/year: 45000
Total fleet buses: 70
% Increase Expected price of fuel/year: 5

Year	Evolution Expected Fuel Price €/lit	Fuel Consumption NO RETROFIT Annual/Bus	Fuel Consumption RETROFIT Annual/Bus	To… Saving €…r/bus	Total fuel Consumption by 100 Buses NO RETROFIT	Total fuel Consumption by 100 Buses RETROFIT	Total Saving €/100buses/year	Accumulated Quantities	Pay Back Mill €
2011	1,1	29.700,00 €	29.700,00 €		2.079.000,00 €	2.079.000,00 €	0,00 €	0,00 €	-3,85 €
2012	1,16	31.185,00 €	24.948,00 €		2.182.950,00 €	1.746.360,00 €	436.590,00 €	436.590,00 €	-2,95 €
2013	1,21	32.744,25 €	26.195,40 €		2.292.097,50 €	1.833.678,00 €	458.419,50 €	895.009,50 €	-2,47 €
2014	1,27	34.381,46 €	27.505,17 €		2.406.702,38 €	1.925.361,90 €	481.340,48 €	1.376.349,98 €	-1,97 €
2015	1,34	36.100,54 €	28.880,43 €		2.527.037,49 €	2.021.630,00 €	505.407,50 €	1.881.757,47 €	-1,44 €
2016	1,40	37.905,56 €	30.324,45 €		2.653.389,37 €	2.122.711,49 €	530.677,87 €	2.412.435,35 €	-0,88 €
2017	1,47	39.800,84 €	31.840,67 €		2.786.058,84 €	2.228.847,07 €	557.211,77 €	2.969.647,11 €	-0,30 €
2018	1,55	41.790,88 €	33.432,71 €		2.925.361,78 €	2.340.289,42 €	585.072,36 €	3.554.719,47 €	0,32 €
2019	1,63	43.880,43 €	35.104,34 €		3.071.629,87 €	2.457.303,89 €	614.325,97 €	4.169.045,44 €	0,96 €
2020	1,71	46.074,45 €	36.859,56 €		3.225.211,36 €	2.580.169,09 €	645.042,27 €	4.814.087,72 €	1,64 €
2021	1,79	48.378,17 €	38.702,54 €		3.386.471,93 €	2.709.177,54 €	677.294,39 €	5.491.382,10 €	2,35 €
						2.844.636,42 €	711.159,11 €	6.202.541,21 €	3,10 €
						2.986.868,24 €	746.717,06 €	6.949.258,27 €	
						27.797.033,07 €	6.949.258,27 €		

With:
Consumption initial ENGINE: 60Lit/100Kms
Save consumption: 20%
Distance: Kms/year: 45.000
Increase of fuel: 5%/year
Total Buses: 70
Public Funding: 50% of total cost
Less Emissions to atmosphere.

Recuperation Time = 8 years



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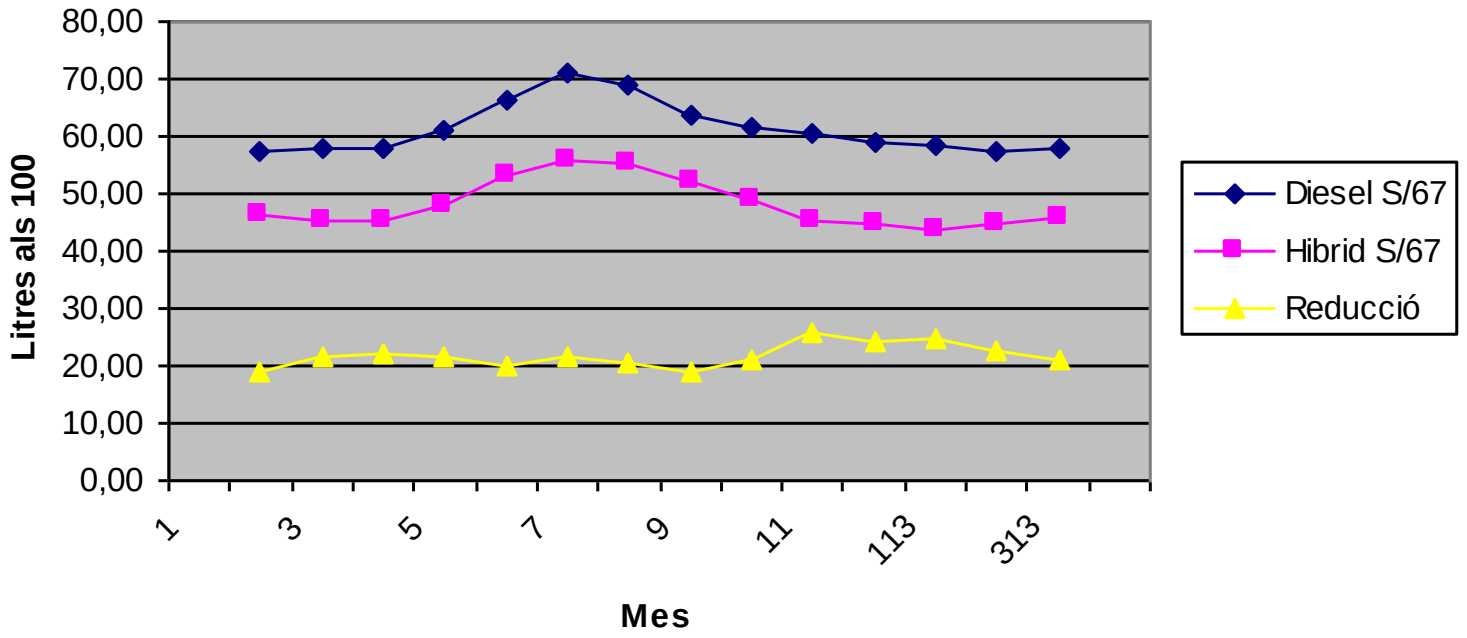
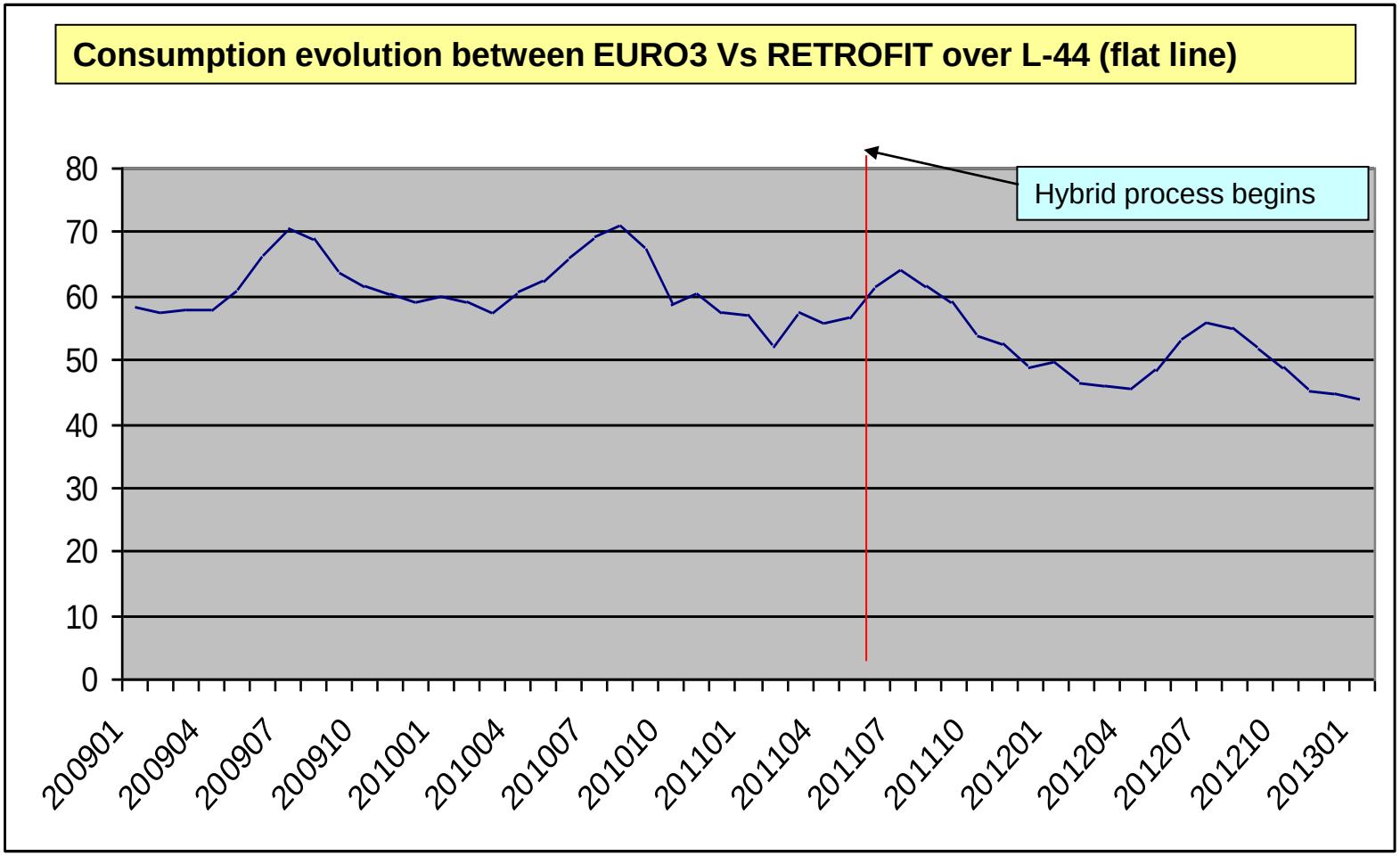
Line-44 (Characteristic=flat) with IVECO Buses

Consumption Lit/100Kms L-44 before and after RETROFIT, one year around.



How consumption improved in IVECO buses before and after RETROFIT on line L44



HYBRID TRANSFORMATION

We have finished 70 DIESEL RETROFIT buses and 12 CNG RETROFIT buses, that are running for TMB bus routes.

Transports Metropolitans de Barcelona

PROJECT 3:
Acquisition New Clean Fleet

Transports Metropolitans de Barcelona

TODAY 2014			
	SIZE	BRAND	UNITS
HYBRIDS	24m	VAN HOOL	3
	12m	CASTROSUA	3
	12m	TATA DENNIS	12
	12m	MAN	16
	12m	VOLVO	1
	12m	IVECO	1
	12m	RETROFIT DIESEL	70
	12m	RETROFIT CNG	11
TOTAL			117

MANUFACTURING 2014			
	SIZE	BRAND	UNITS
ELECTRIC	12M	BYD (Full Electrical)	1
HYBRIDS	12m	IVECO	5
	12m	VOLVO	4
	12m	MAN	11
	12m	RETROFIT CNG	2
	TOTAL		23

OVERVIEW HYBRIDS

DIESEL-HYBRID (serial configuration)

Model: MAN NS CITY

Engine: MAN

Power Engine: 250 CV

HYBRID system: Siemens_ Elfa system.

Electric motor: 122 kW

Generator: 85 kW

Storage system: ULTRACAPS

DIESEL-HYBRID (serial configuration)

Model: TATA-HISPANO Habit Enviro 350H

Engine: CUMMINS

Power Engine: 185 CV

HYBRID system: BAE system

Electric motor: 175 kW

Generator: 145 kW

Storage system: BATTERIES (12kWh)

DIESEL-HYBRID (serial configuration) PLUG IN

Model: CASTROSUA TEMPUS

Engine: CUMMINS

Engine Power: 136 CV

HYBRID system: Siemens_ Elfa system.

Electric motor: 134 kW

Generator: 85 kW

Storage system: BATTERIES 90kWh (Zebra)

DIESEL-HYBRID (serial configuration)

Model: VAN HOOL EXQUICITY

Engine: MAN

Engine Power: 290 CV

HYBRID system: BAE.

Electric motor: 200 kW

Generator: 180 kW

Storage system: BATTERIES 41,1kWh (ACTIA)

DIESEL-HYBRID (PARALEL configuration)

Model: VOLVO HYBRID

Engine: VOLVO

Engine Power: 218 CV

HYBRID system: VOLVO.

Electric motor: 120kW

Generator: I-SAM

Storage system: BATTERIES 4,8 kWh

DIESEL-HYBRID (SERIAL configuration)

Model: IVECO-CITELIS HYBRID

Engine: IVECO

Engine Power: 161 CV

HYBRID system: BAE.

Electric motor120 kW

Generator: BAE

Storage system: BATTERIES 11 kWh (BAE)

FULL ELECTRIC

ELECTRIC

Model: BYD

HYBRID system: BYD.

Electric motor: BYD 180 kW

Storage system: BATTERIES 324 kWh (BYD_ LiFePo)

Thank you for your attention.

Transports Metropolitans de Barcelona