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## THE INTRODUCTION OF E-MOBILITY: TESTIMONIAL FROM THE CITY OF MADRID

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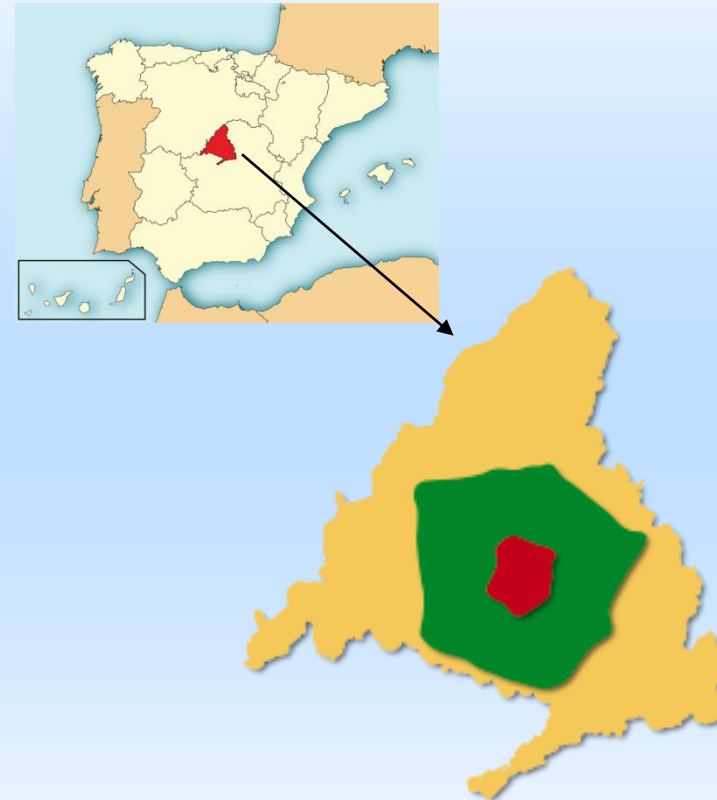
Mumbai, April 29<sup>th</sup>, 2015



- Brief introduction to Madrid and EMT (figures)
- Policies favoring e-mobility in Madrid
- EMT e-background (chronologically):
  - Electric transmission buses
  - Hydrogen
  - Diesel-Hybrid
  - Retrofit diesel buses
  - e-microbuses
  - CNG-Hybrid
  - e-buses tests
- Additional experience on e-mobility

# Madrid figures

- Madrid region is one of the 17 autonomous regions of Spain
- It has 179 municipalities and a population of more than 6 million inhabitants (3.2 million in Madrid City)
- 8,028.5 km<sup>2</sup>



# EMT tasks

- Providing bus service within the municipality of Madrid
- Surveillance of dedicated bus lines
- Managing the municipal tow truck service
- Managing the public underground parking facilities
- Managing the publicity at bus shelters and buses
- Internal and external Consultancy (i.e. assisting Madrid City Council at European Projects)



# EMT Main Figures

- Created in 1947. 100% owned by Madrid City Council
- 1.903 buses
- 88 tow trucks
- 16 underground parking facilities
- 5 Depots
- 203 bus routes (176 daytime/27 night service),
- 4,629 bus shelters
- 8,500 workers
- 404 million travels / year
- 91 million km / year
- Annual Turnover: 455 million €



# EMT FLEET

Our fleet uses different fueling technologies:

- Diesel
- Biodiesel
- CNG (Compressed Natural Gas)
- Fully electric
- Diesel Hybrids
- CNG Hybrids



**EMT was the first company in Europe to use CNG Hybrid buses**

- **Peru:** Currently operating in Lima (COSAC I) by Transvial Lima Company and analyzing other alternatives in that country: Arequipa, Piura
- **Ethiopia:** Completed consulting activities for the urban transport company of Addis Ababa
- **Colombia:** Negotiating for the implementation of IT technologies in several cities of the country
- **Brazil, Mexico, Santo Domingo:** Established contacts to participate with authorities and / or local companies for operate and / or implement ITS technologies
- **Ukraine, Ivory Coast, Romania :** Sale of secondhand buses
- **Bursa (Turkey):** Consultancy for the development of Public Service Contract of the new public LRT transport system of the city.
- **Mendoza (Argentina):** Training of technical staff and top management of a public transportation company “El Cacique”.
- **La Paz (Bolivia):** Consultancy for a BRT system at La Paz
- **Kyzylorza (Kazajistán):** Consultancy for the creation of a BRT with CNG buses
- **Da Nang (Vietnam):** Consultancy for the technical maintenance of a BRT and conventional bus lines service

# EMT Differential factors

- EMT is a transport operator in large and complex cities and in different social and economic environments (Madrid & Lima) and has done transport consultancy for many other cities
- EMT has experience in the use of different traction systems and alternative energies
- EMT has wide knowledge in demand studies and design of urban transport routes
- EMT is capable of designing buses, bus stations, garages, depots, fueling facilities and CNG fueling facilities
- EMT is leader in the application of IT technologies into urban transport, with our own developments or in association with other suppliers

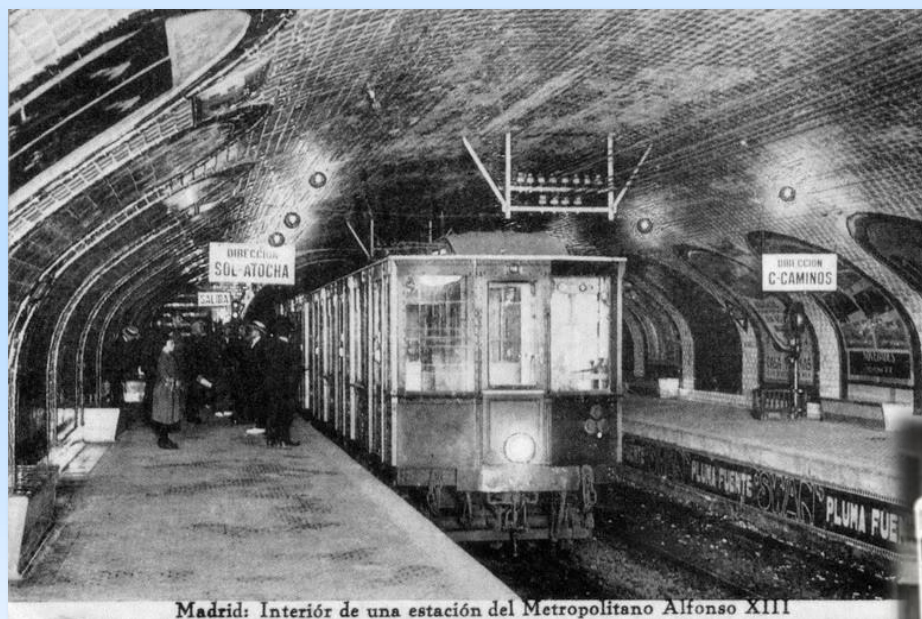


And we can share all our knowledge and know-how!



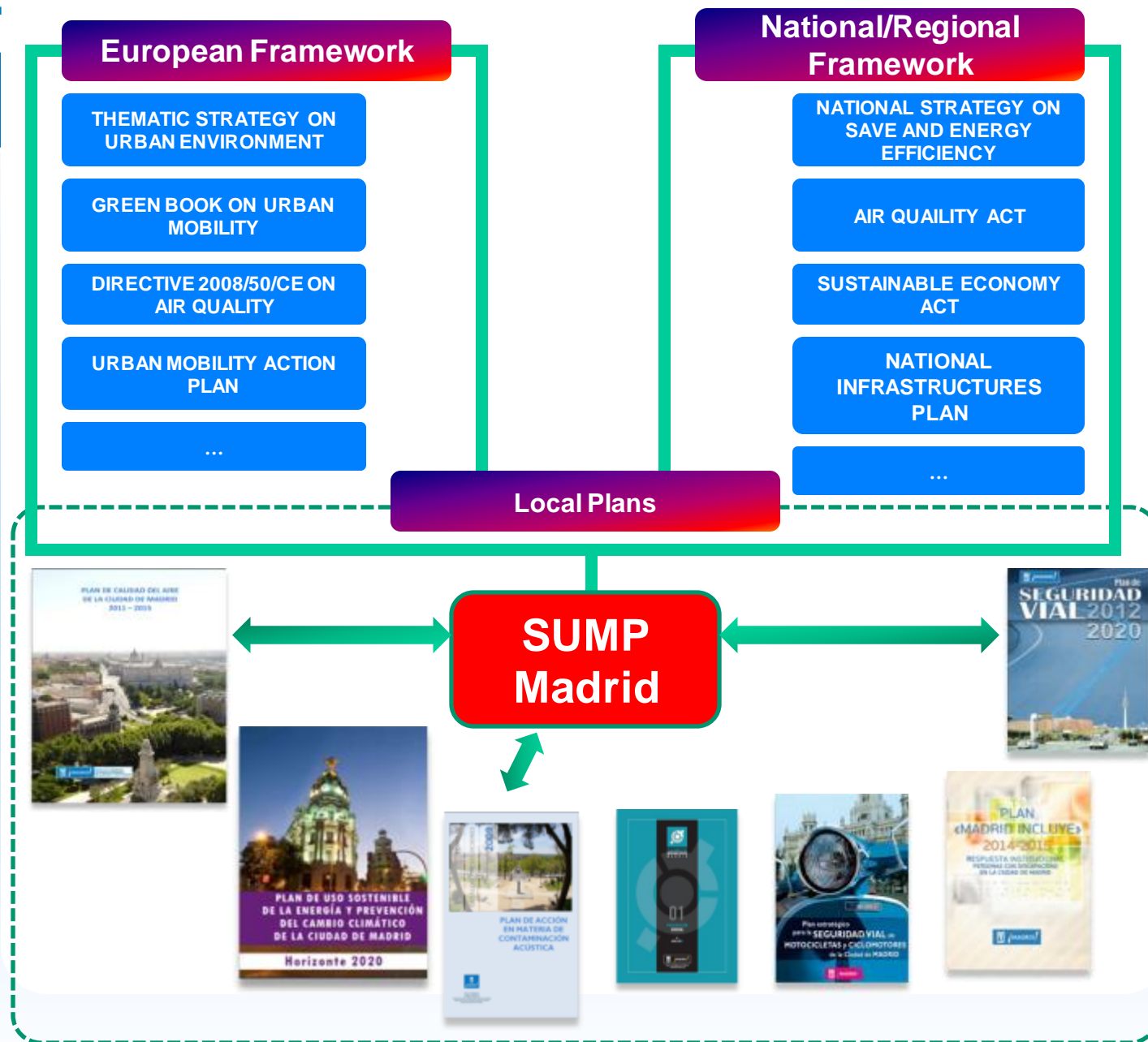
# ELECTRIC PT IN MADRID

...1919

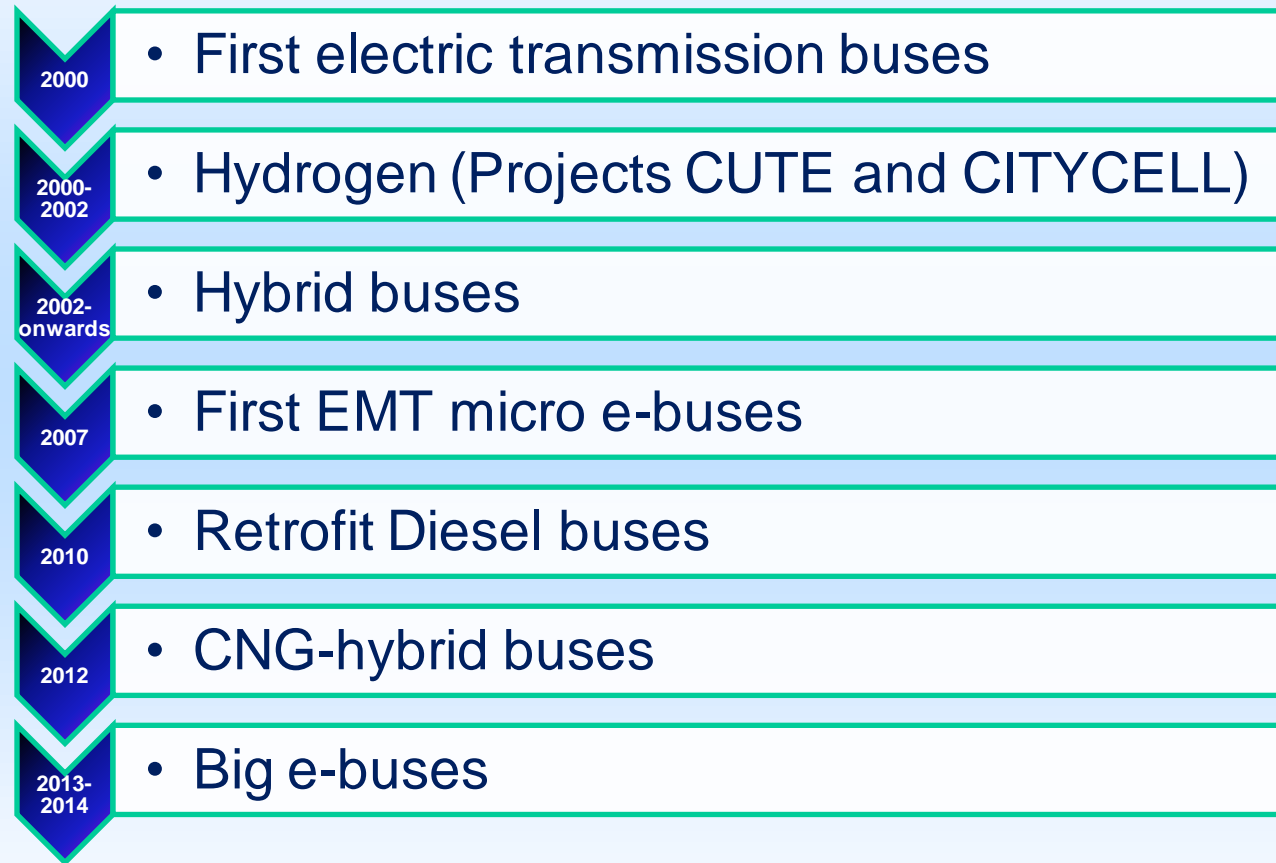


Madrid: Interior de una estación del Metropolitano Alfonso XIII





# EMT e-BACKGROUND



# Electric transmission buses



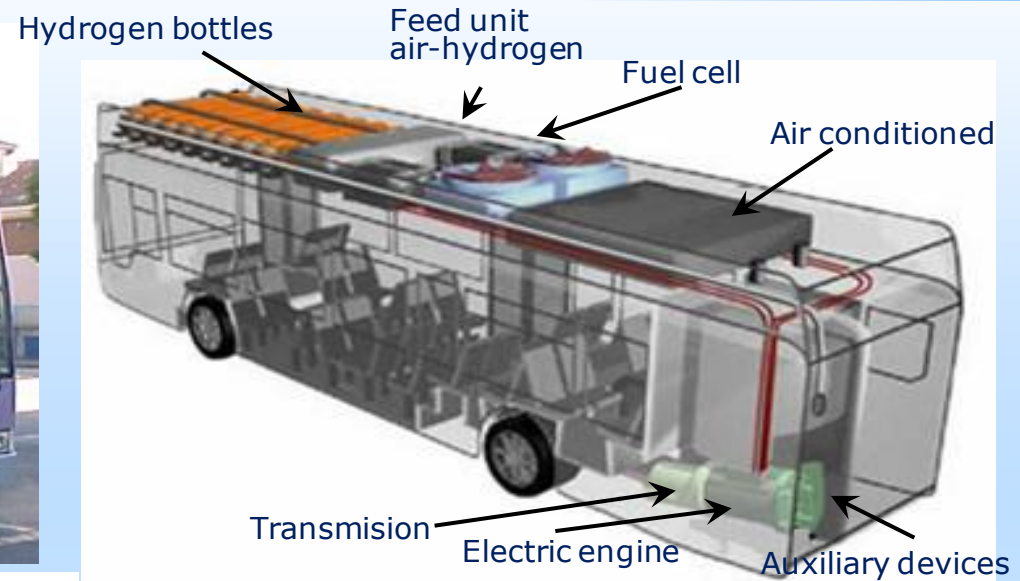
- Mercedes CITO
- 20 units years 2000/2001
  - 8 and 9 m
  - 12 / 16 seats
  - 45 / 55 passengers
- Low floor and ramp
- Aluminium
- Smooth ride

- No batteries. Diesel engine as generator
- Emissions: lower than eq. ICE microbus
- More efficient: better performance of cinematic flow

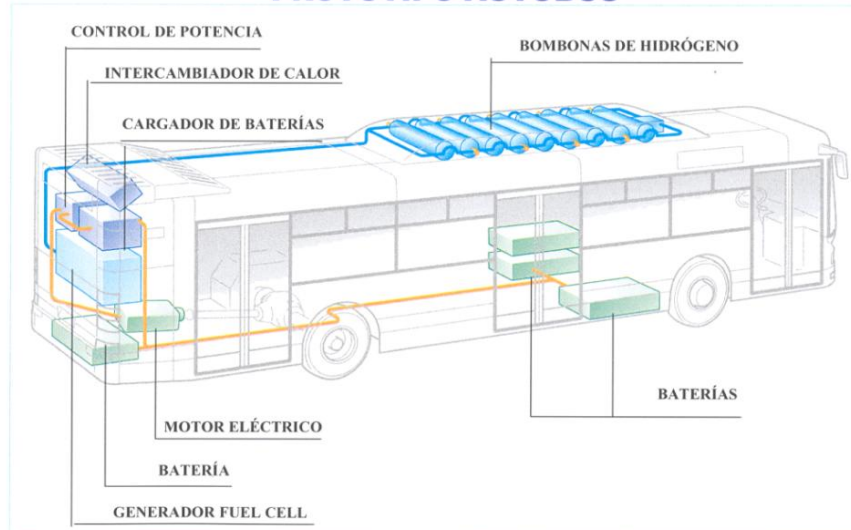




# Hydrogen: CUTE and CITYCELL projects



## PROTOTIPO AUTOBUS



## HYBRID buses

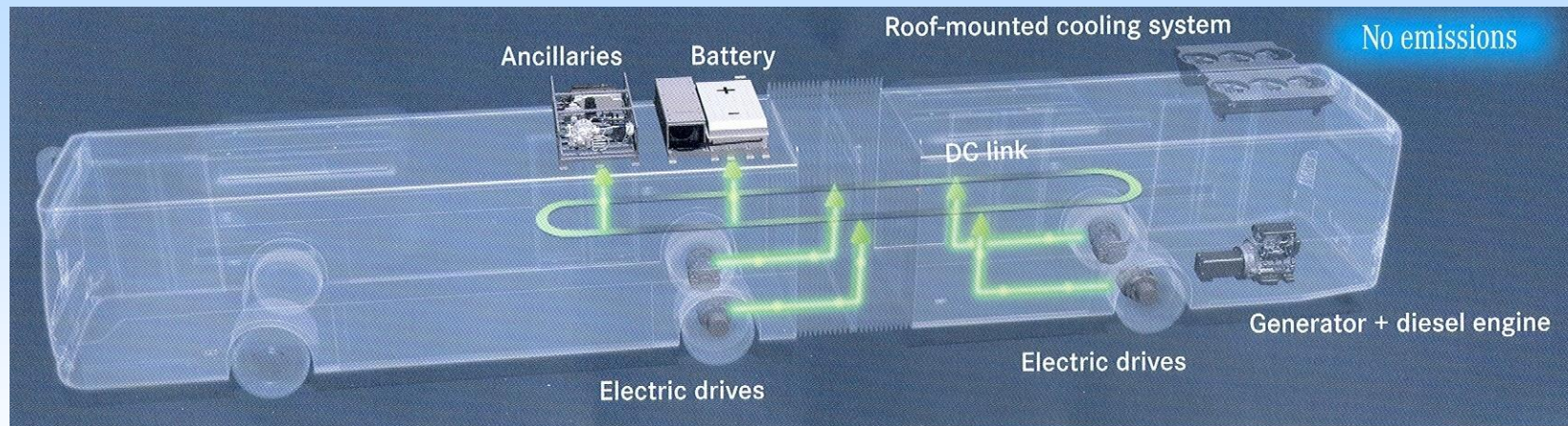


Consumption reduction:  
between 24 and 30 % (vs. Euro IV diesel bus)



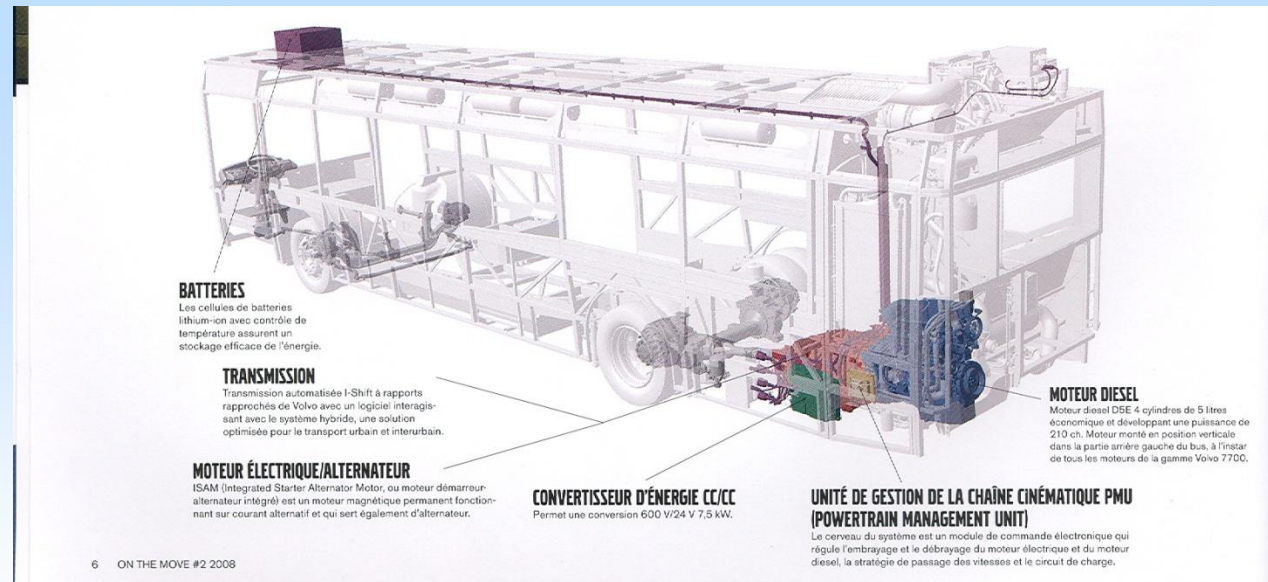
## MERCEDES BENZ- Serial hybridization

- Diesel engine 160 kw with 4.8 liters (38% power reduction)
- 4 electric engines at each wheel, with 80 kw each
- Range (electric mode): 3 km
- Ion-Lithium batteries (550 kg weight)
- Consumption and CO2 emissions reduction: 30%



# VOLVO- Parallel hybridization

- Diesel engine 155 kw with 5 litres (35% power reduction)
- 1 electric engine to the transmission, with 120 kW
- Ion-Lithium batteries
- Consumption and CO2 emissions reduction: 35%



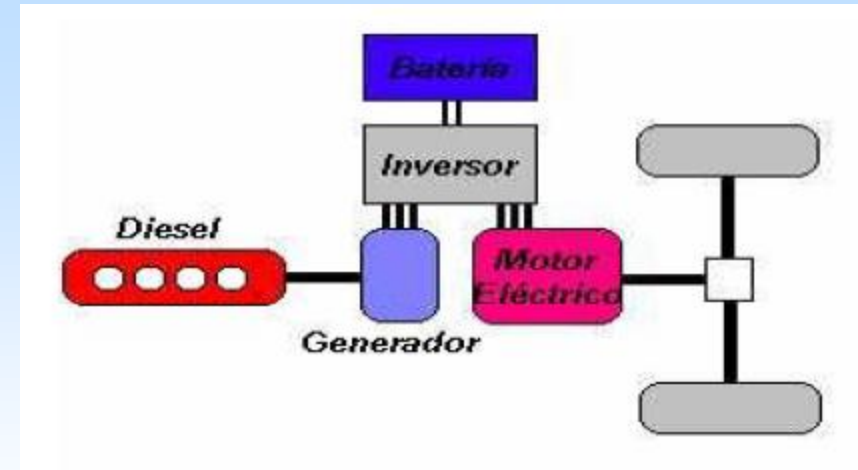


## MAN- Serial hybridization



## CASTROSUA.- Serial hybridization

- Zebra type batteries (72 kWh at 620 V)
- Regenerative braking: up to 30% of the energy.
- Pure electric traction system: Silent and no local emissions
- The bus driver can choose to run in pure electric mode
- Small diesel engine to charge batteries



## First EMT micro e-buses (2007)

- Front transmission 100% electric
- Voltage: 85 V DC
- Power: 27.2 kW
- Braking energy recovery
- Zebra type batteries Na-Ni/Cl<sub>2</sub>
- Battery weight: 2 x 294 kg
- Stored energy: 72 kWh
- Temperature range 240 - 330°C



- Size: 5,3 x 2,0 x 2,9 m
- Max. weight: 3.800 kg



Commercial speed: 6 km/h  
Silent and no local emissions  
Average consumption:  
0.84 kWh/km  
20 units



- **Centric location**
- **Narrow streets**
- **Low commercial speed**
- **Versatile**

**M2**  
minibús

**SEVILLA**  
(Alameda)

**Gran Vía**

**Valverde**

**Corredora Baja de San Pablo**

**Pz de España**

**Reyes**

**Amiel**

**Alberto Aguilera**

**Serrano Jover**

**ARGÜELLES**  
(Alberta Argüelles)

**minibús**

Horario y frecuencia de servicio (excepto viernes y festivos festivos)				
Tipo de día	Rutas de salida en sentido principal (sevilla - alberta argüelles)		Rutas	Frecuencia
	Sevilla	Argüelles		
Lunes y Viernes laborables	0,05 - 15,00	0,00 - 19,55	De 0,00 a 0,20 De 7,00 a 13,0 De 13,0 a 17 De 17 a 19	semana 20-15 min semana 10-10 min semana 15 min semana 10-10 min
Sábados laborables	0,05 - 15,00	0,00 - 19,55	De 0 a 1 De 7 a 11 y 19 a 21 De 19 a 19	semana 15 min semana 10-10 min semana 10-10 min
Domingos y Festivos	Se servicio	Se servicio		Se servicio





## Charging stations at Carabanchel depot



## Retrofit diesel buses (2010)

- Financed by IDAE (“Electrobus” strategic project)
- Turning Biodiesel and CNG into hybrids
- 4 buses (currently in service)
- Fuel saving: 18 %



**Retrofit EMT**

# Retrofit diesel buses

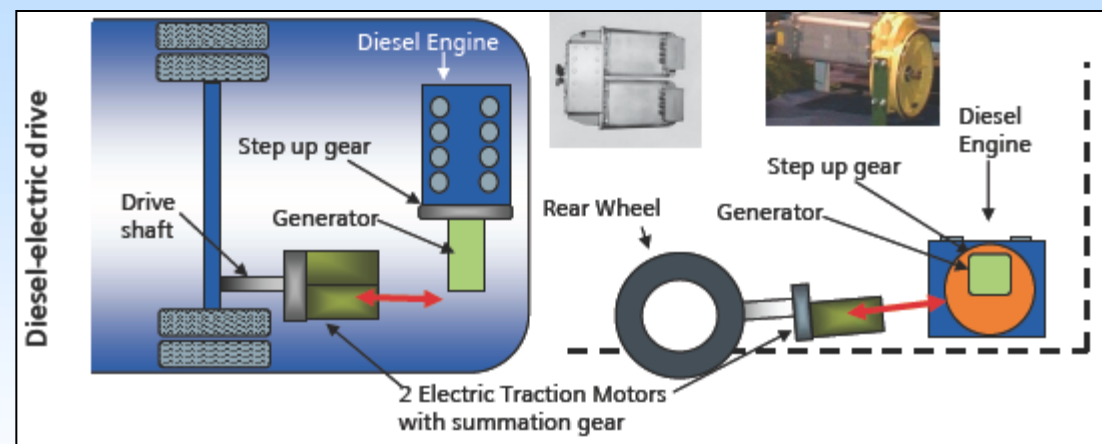
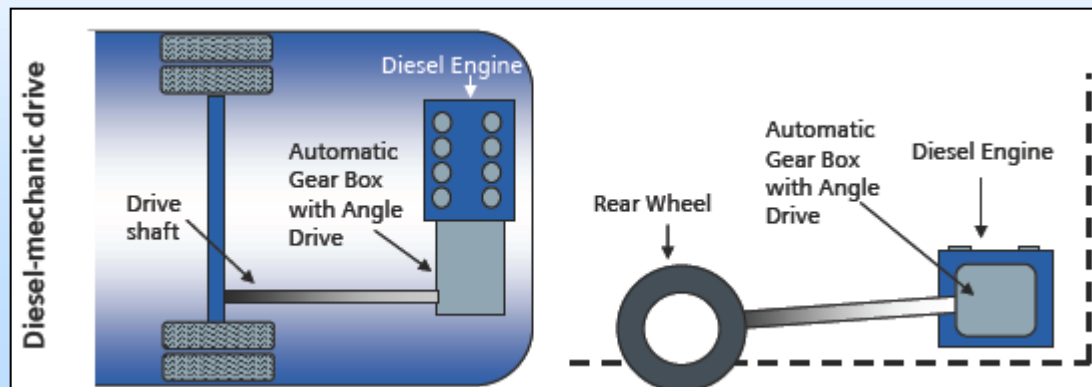
Serial system

Ultracaps

Diesel engine: Stop / Start

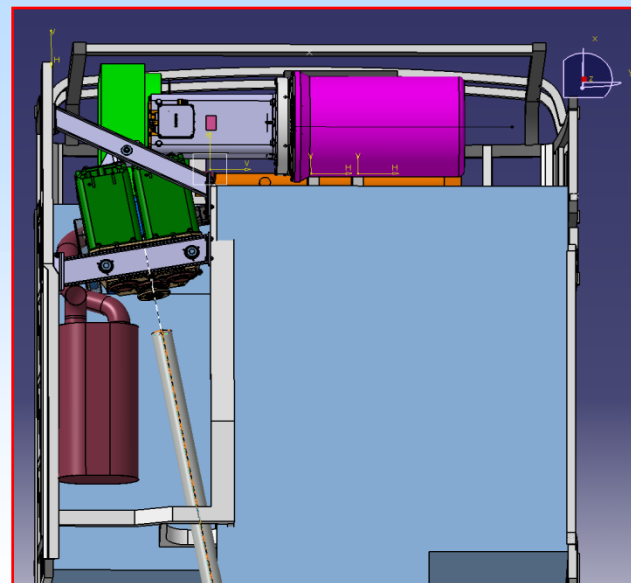
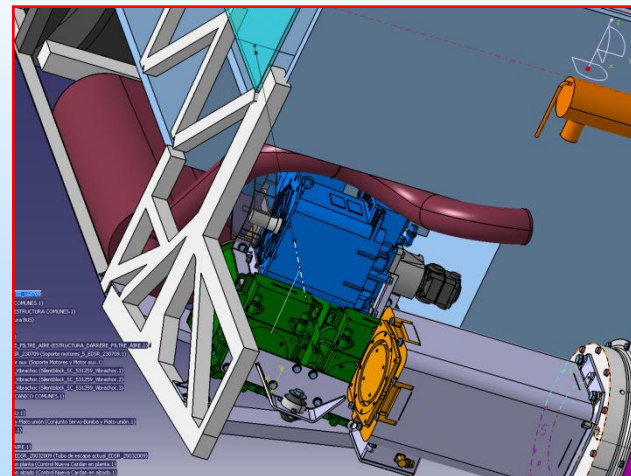
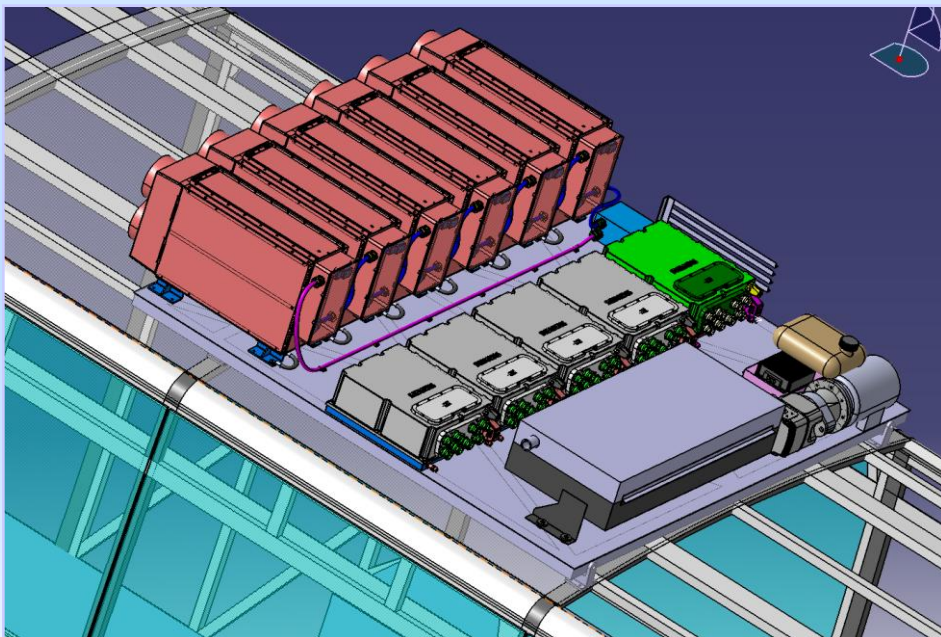
2 electric engines

Eliminating the gearbox



# Retrofit diesel buses

## MECHANIC INTEGRATION





# CNG-hybrid buses (2012)

Spanish made thanks to EMT demand (first units june 2012)

**13 CASTROSUA TEMPUS buses**

**Serial Hybridization**

**Emission reduction strategy**

**10 TATA HISPANO buses**

**Serial Hybridization**

**Consumption reduction strategy**



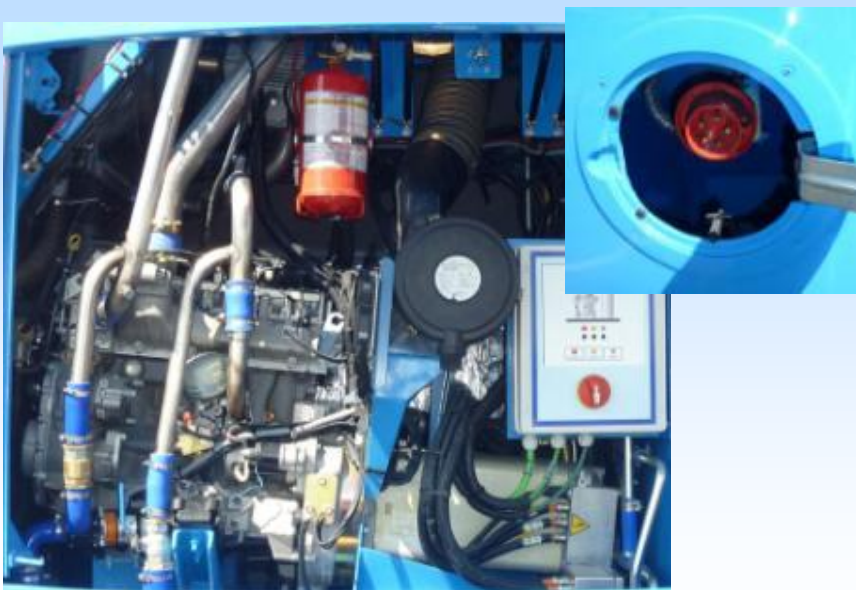
**TATAHISPANO**



**CASTROSUA**

## CASTROSÚA TEMPUS GNC: june 2012

- Two engines:
  - 1 Thermal Iveco Compressed Natural Gas (CNG) 100kW
  - 1 Electric Traction Siemens 134 kW
- Serial hybridization
- Energy recovery in braking
- Plug-in to the grid
- Stop & Start System
- Ability to circulate in pure electric mode.
- Autonomy in pure electric traction (minutes/km): 60/150 km
- Electric transmission only to the rear wheels
- Electric power to the wheel: 67x2 kW



- 3 batteries traction type "zebra" (Ni-Na / Cl<sub>2</sub>)
- Voltage: 520 V AC
- Max. Intensity: 145 A
- Voltage: 620 V DC
- Power: 19 kW / h
- Intensity: 32 A / h
- Intensity max. A discharge 90
- Intensity max. with regenerative braking load 30 A
- Internal Operating Temperature 245 ° C - 360 ° C
- Max. Environmental temperature 50°C
- Total Capacity: 96 Ah (32 Ah x 3)

**Consumption saving (€) up to 45% (vs. Diesel),  
and about 25-30% vs. CNG**

## TATA HISPANO TML CS25 GNC

- Two engines:
  - 1 “Cummins” Thermal Compressed Natural Gas (CNG) to 145 kW
  - 1 Electric Traction “Siemens” with 134 kW
- Serial hybridization
- Energy recovery in braking
- Stop & Start System
- Rear wheels only Electric
- Electric power to the wheel: 67x2 kW



- 8 modules of lithium ions
- Voltage: 520 V AC
- Max. Intensity: 145 A
- Voltage: 660 V DC
- Intensity: 8.8 Ah
- Internal Operating temperature: 16°C - 40°C
- Max. ambience temperature: 50°C
- Total capacity: 58 kWh

**Consumption saving (€) up to 30%  
(vs. Diesel)**



## Charging stations at Carabanchel depot



15 charging points at 25 A  
1 charging point at 50 A  
(own engineering design)



# BIG E-BUSES TEST IN EMT



		BUS
Consumption	kWh / km	1,97
Range	km	85-170
	hours	7-14

## Additional experience on e-mobility

- 100% electric microbus
- Bredamenarinibus, model Zeus
- 6,5 m lenght (13 people capacity)
- Internal/Institutional services
- Ion-lithium batteries 58 kWh
- Electric engine 30 kW
- Max. speed 44 Km/h
- 120 Km range (or 9 hours functioning in urban circuit)
- Standard charging (8 hours) o fast charging (3 hours)
- Internal/institutional use





# Additional experience on e-mobility



- **DEDICATED BUS LINES SURVEILLANCE SERVICE (2012)**
- **9 electric cars**
- **THINK brand (model CITY)**
- **ZEBRA batteries 23 kWh**
- **Electric engine 30 kW**
- **Range: 200 km**
- **Max. speed: 120 km/h**





**Thank you very much!**

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