

Comparative Study on Exhaust Emissions from Diesel- and CNG-Powered Urban Buses

Patrick COROLLER & Gabriel PLASSAT

(French Agency of Environment and Energy Management)

Presented by

Dr. Thierry SEGUELONG

(Aaqius&Aaqius)



ADEME



Outlines of the presentation

- **ADEME Program**
- **Program Evaluations on Diesel & CNG Buses**
- **Tests Results**
 - **Exhaust Emissions**
 - **Consumption**
- **Green House Gas Emissions**
- **Economical Study**
- **Conclusions**



Outlines of the presentation

- **ADEME Program**
- Program Evaluations on Diesel & CNG Buses
- Tests Results
 - Exhaust Emissions
 - Consumption
- Green House Gas Emissions
- Economical Study
- Conclusions



ADEME National Evaluations

Objective:

- development of Public Transports in urban area with clean image and reduction of exhaust emissions:
 - improvement of performance of existing fleet vehicles, using new fuels (Diesel, reformulated fuels, CNG, LPG, RME...) and adapted exhaust emission control systems...
 - replacement of old vehicles with promoting clean technologies (Diesel, hybrid, electric, fuel-cells...)
- diversification in energy source for Public Transports
- customers acceptance
- *Long term evaluations in the real urban area started in 1998*



Outlines of the presentation

- ADEME Program
- Program Evaluations on Diesel & CNG Buses
- Tests Results
 - Exhaust Emissions
 - Consumption
- Green House Gas Emissions
- Economical Study
- Conclusions



ADEME National Fleet Evaluations

Part of a comprehensive program based on evaluation of **6 sites** between 1998 and 2003+

- *evaluation of emissions*
- *follow-up on city site*
- *technical diagnosis*
- *customers acceptance*



ADEME



Specific Evaluated Bus Vehicles

3 CNG-powered Buses (3 technologies)

AGORA Renault VI:

lean combustion, w/ carburetor, w/ Oxicat

HEULIEZ Volvo engine:

lean combustion, w/multipoint injection, w/ Oxicat

Mercedes:

stoichiometric combustion, w/ TWC

4 Diesel-powered Buses (EURO 2 – 1995/1996)

AGORA 10 L Renault VI (x2)

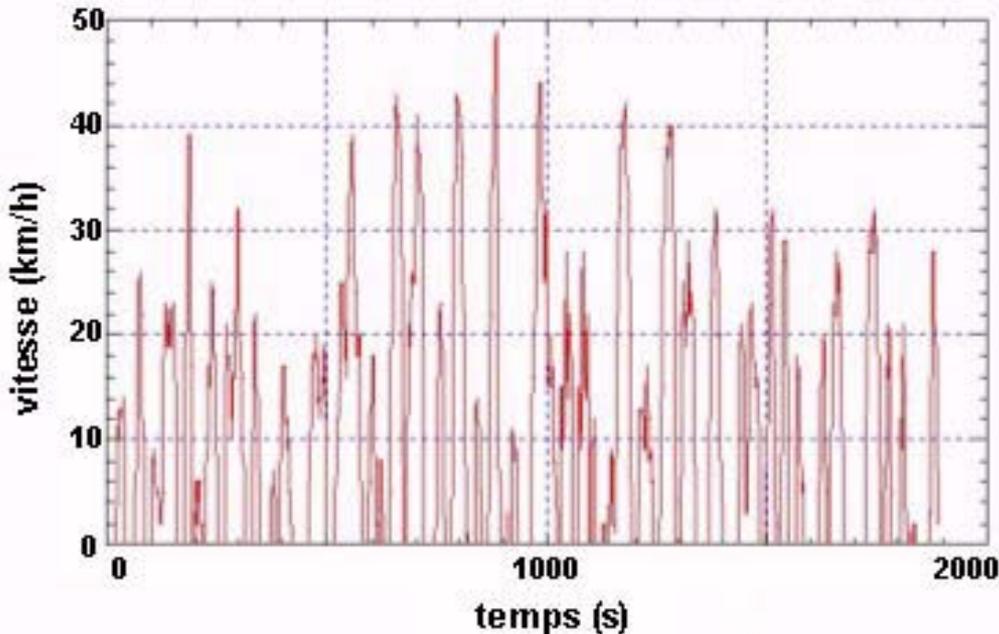
Mercedes 12 L O405 (x2)



Comparative Study (UTAC*)

“In situ” tests in term of technical and environmental performance

Exhaust emissions (CO, HC, NOx, PM), Carbon balance and technical diagnosis of bus fleets



* *Union Technique de l'Automobile, du Motocycle et du Cycle*

AQA-RATP Cycle
Paris City line # 21
(average speed of 10,5km/h)

Outlines of the presentation

- ADEME Program
- Program Evaluations on Diesel & CNG Buses
- **Tests Results**
 - Exhaust Emissions
 - Consumption
- Green House Gas Emissions
- Economical Study
- Conclusions



CO Exhaust Emissions

in g/km

DIESEL

CNG



HC Exhaust Emissions

DIESEL

CNG



NOx Exhaust Emissions

DIESEL

CNG



PM Exhaust Emissions

DIESEL

CNG



Non-Regulated HC Emissions

at the initial point, mainly **Methane**, **C2** (ethane, ethene), **C3** (propane, propene); no significant emissions of other hydrocarbons (except for carburetor-based technology)

- with carburetor-based technology, high non-regulated hydrocarbons levels were observed, with ethane (732mg/km), C3, C4, C5, C6, acetaldehyde (150mg/km) and acrolein (about 10 times higher than other CNG technologies)

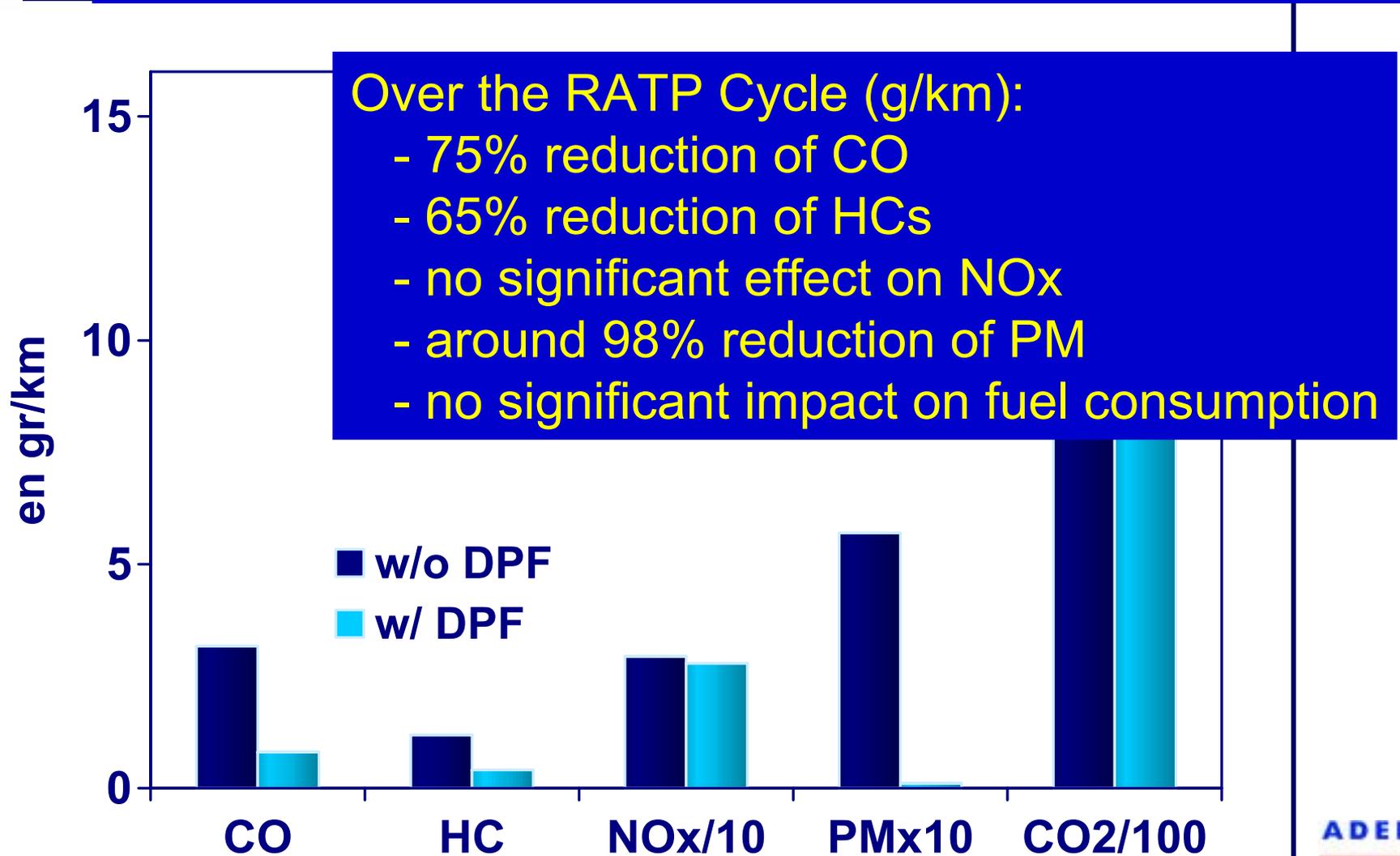
after one year service, increase of aldehydes, regardless of CNG technologies, and heavy hydrocarbons (> C5)

- effect of lubricant (consumption, combustion)

Diesel non-regulated emissions: more specific, without significant difference between buses types.

- heavy hydrocarbons (>C5),
- oxygenated related to formaldehydes (50%) and acetaldehyde (25%).

DPF Effect on Exhaust Emissions

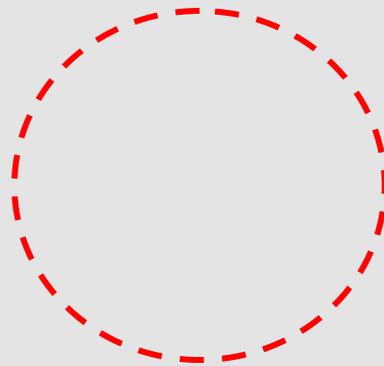


CNG Consumption

Over AQA-RATP Cycle: +30 to +60% depending on the bus

On Site: +20 to +45% (depending on the bus technology, urban conditions, air conditioning, compartment heating)

1 Nm³/100km is equivalent to 1 l/100km Diesel fuel



NICE area (South of France)

winter: 78 Nm³/100km

Summer: 85 Nm³/100km

» Air conditioning system

ADEME



Outlines of the presentation

- ADEME Program
- Program Evaluations on Diesel & CNG Buses
- Tests Results
 - Exhaust Emissions
 - Consumption
- **Green House Gas Emissions**
- Economical Study
- Conclusions



Green House Gas Emissions

Production
Compression
Refinery

CH₄
GWP=25

CO₂
Exhaust

ADEME



Outlines of the presentation

- ADEME Program
- Program Evaluations on Diesel & CNG Buses
- Tests Results
 - Exhaust Emissions
 - Consumption
- Green House Gas Emissions
- **Economical Study**
- Conclusions



Preliminary Cost Study

CNG	EURO 2 Diesel fitted w/DPF
Over-cost : average of 30,000€/bus	Average cost of DPF System: 4,500 to 6,000€ (passive)
- fuel penalty: +1,34 - and compressed gas station: 450 to 500,000 € (investment)	Low Sulfur Fuel: 0,03 €/l
Security, Refilling speed, Maintenance (spark-plug, engine parts...)	<ul style="list-style-type: none"> - DPF regeneration machine (passive) - DPF cleaning (60 to 100,000km) - additional cost for Active DPF - and NOx after-treatment



Outlines of the presentation

- ADEME Program
- Program Evaluations on Diesel & CNG Buses
- Tests Results
 - Exhaust Emissions
 - Consumption
- Green House Gas Emissions
- Economical Study
- **Conclusions**



Average performance summary

Pollutants (g/km)	RVI AGORA Diesel	Mercedes Diesel	RVI AGORA CNG	Volvo CNG	Mercedes CNG
Max. Power	110 kW	136 kW	103 kW	127 kW	103 kW
CO	3,90	1,8	5,4	0,6	12,0
HCs	1,2	1,2	8,4	5,3	5,0
NOx	30,2	20,0	14,8	13,5	8,3
PM	0,42	0,28	0,036	0,025	0,026
Consumption (line 21) /100km	61 lit.	56 lit.	78 Nm3	91 Nm3	81 Nm3
GHGE (g/km)	1800	1670	2200	2090	2240

1 Nm3/100km is equivalent to 1 l /100km Diesel fuel



Comparison trends & Summary

	CO	HC	NOx	PM	NRP	GHE	D	I	O	A
Diesel (EURO 2)										
Diesel w/ DPF	+	+	=	+	+	=	=	-	=	-
CNG		+	+	+	+	--	+	--	=	-



D: Diversification (energy)
I: Investment
O: Operation
A: Adaptation



Trends and Perspectives

Diesel: fitted with DPF and NOx control
improved Direct Injection Diesel Engine
Diesel fuel quality

CNG: technology developments and improvements
specific exhaust emissions control devices
- sensors, specific CH₄ after-treatment
adapted maintenance
specific lubricant
combustion improvements (» CO₂ emission)
local organization (central compressed machine)

Target: 20% CNG in Public Transports in Y2020

ADEME

