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

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# Outlines of the presentation

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

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# 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*

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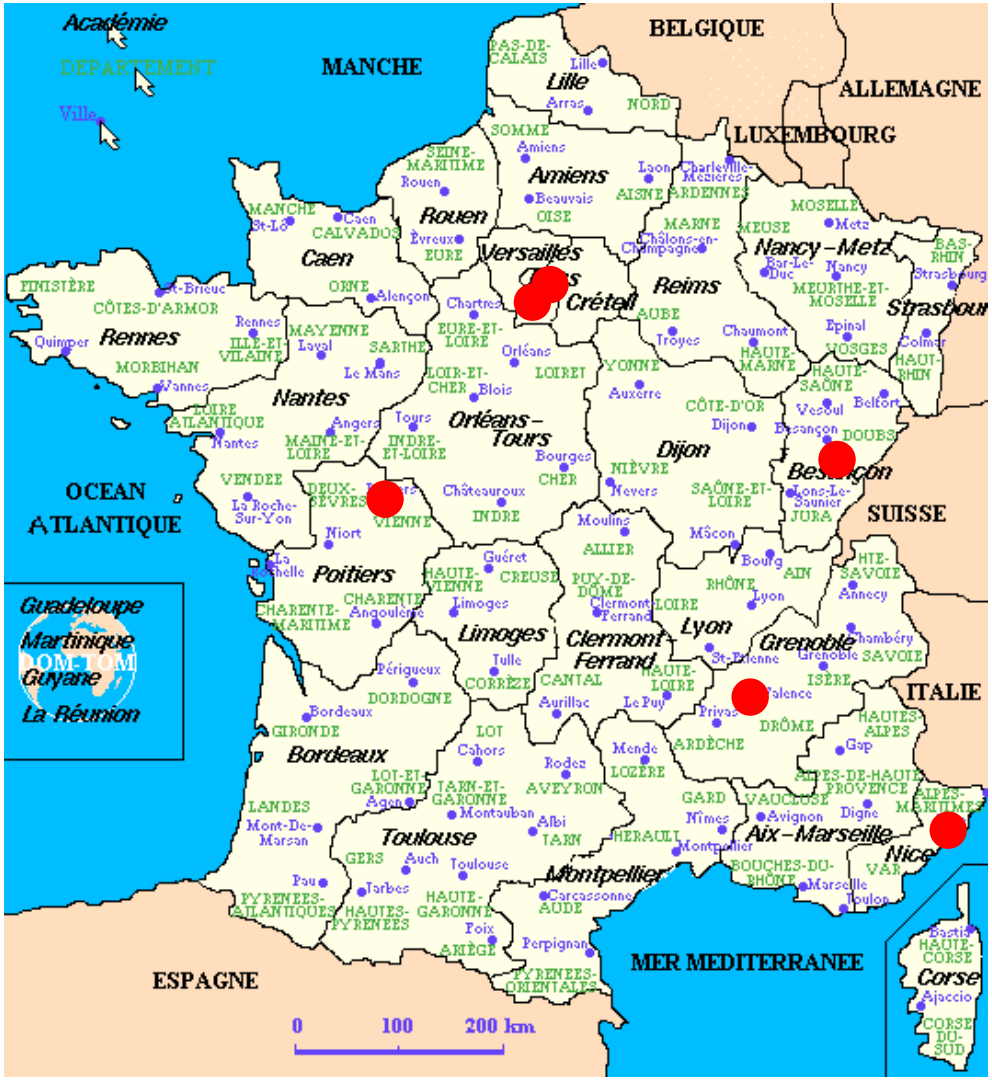
# ADEME National Fleet Evaluations

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*

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# 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)

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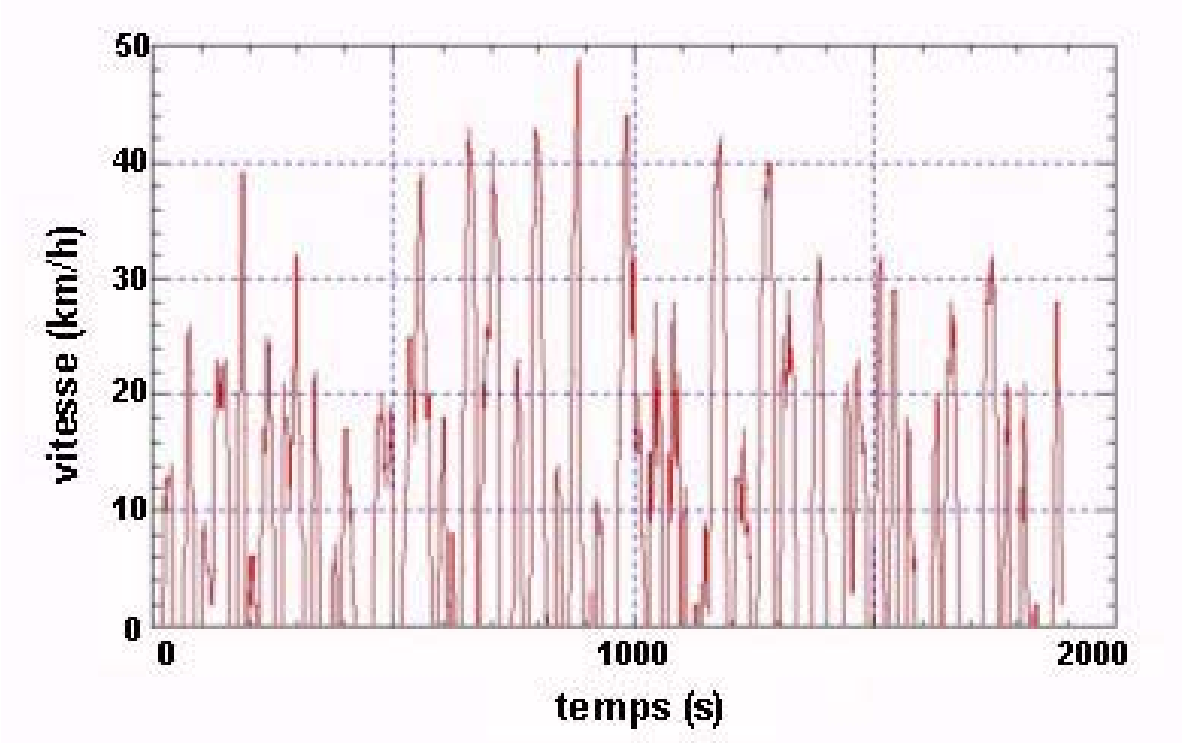
# Comparative Study (UTAC*)

**"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)

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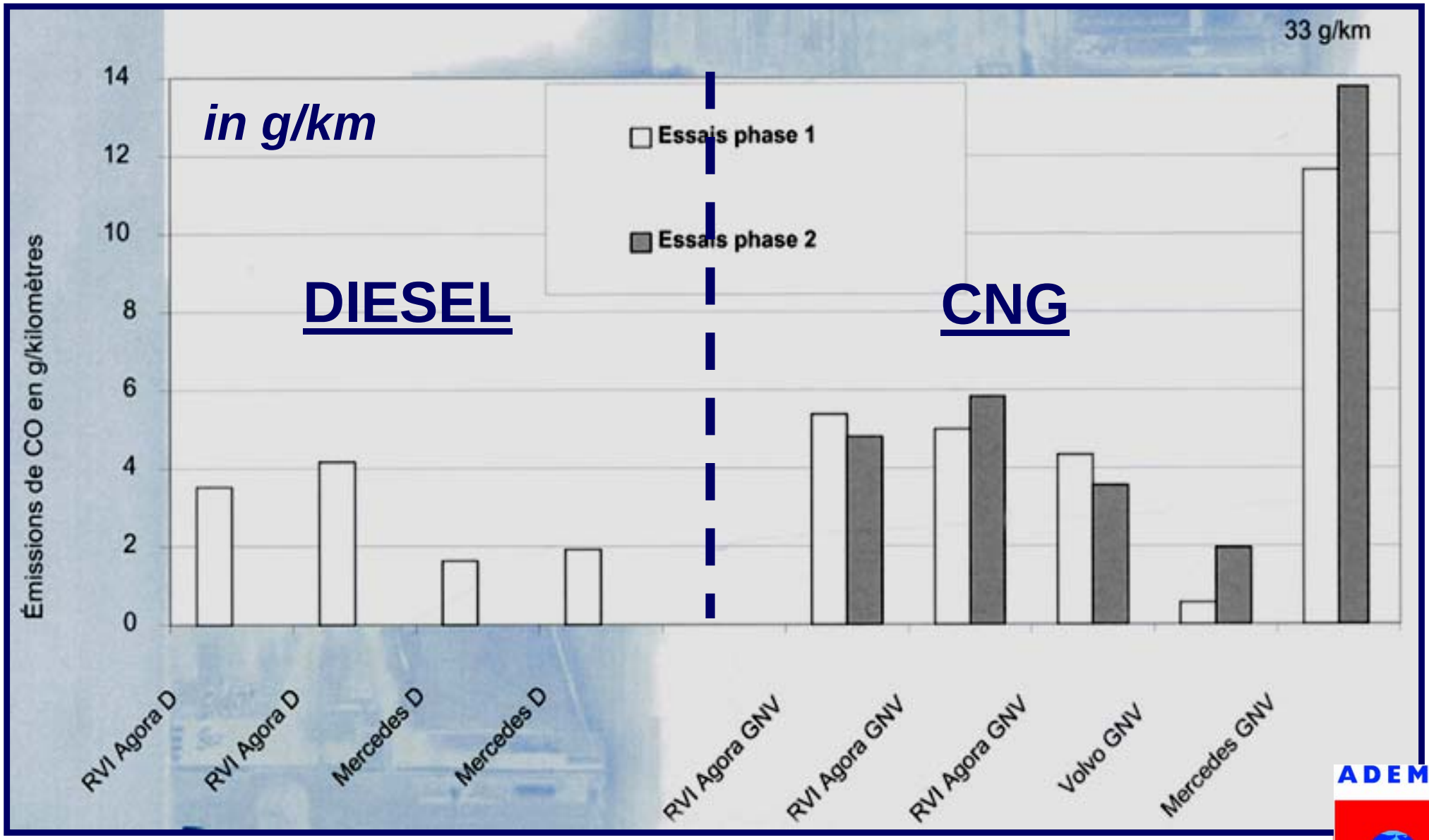
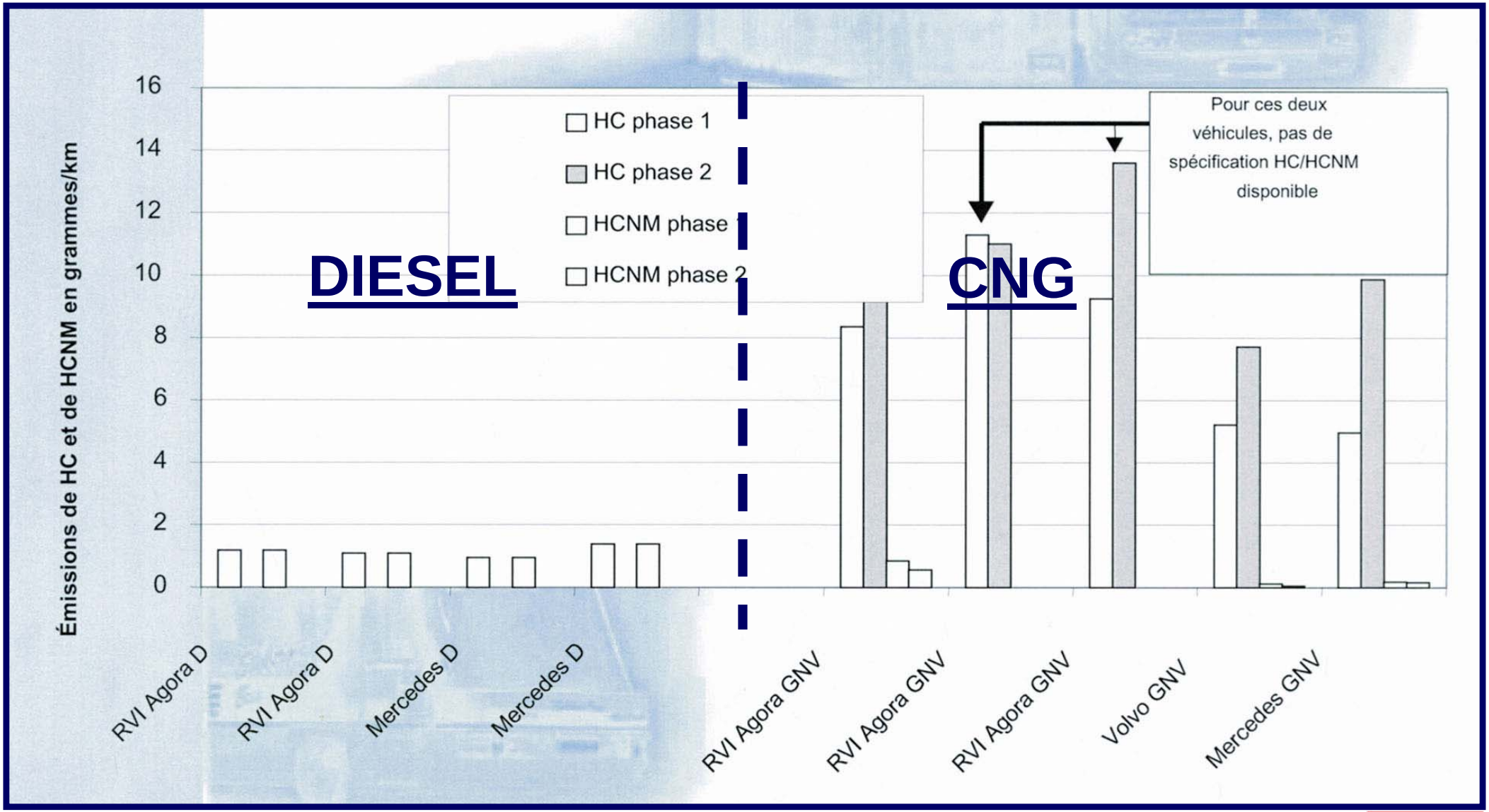
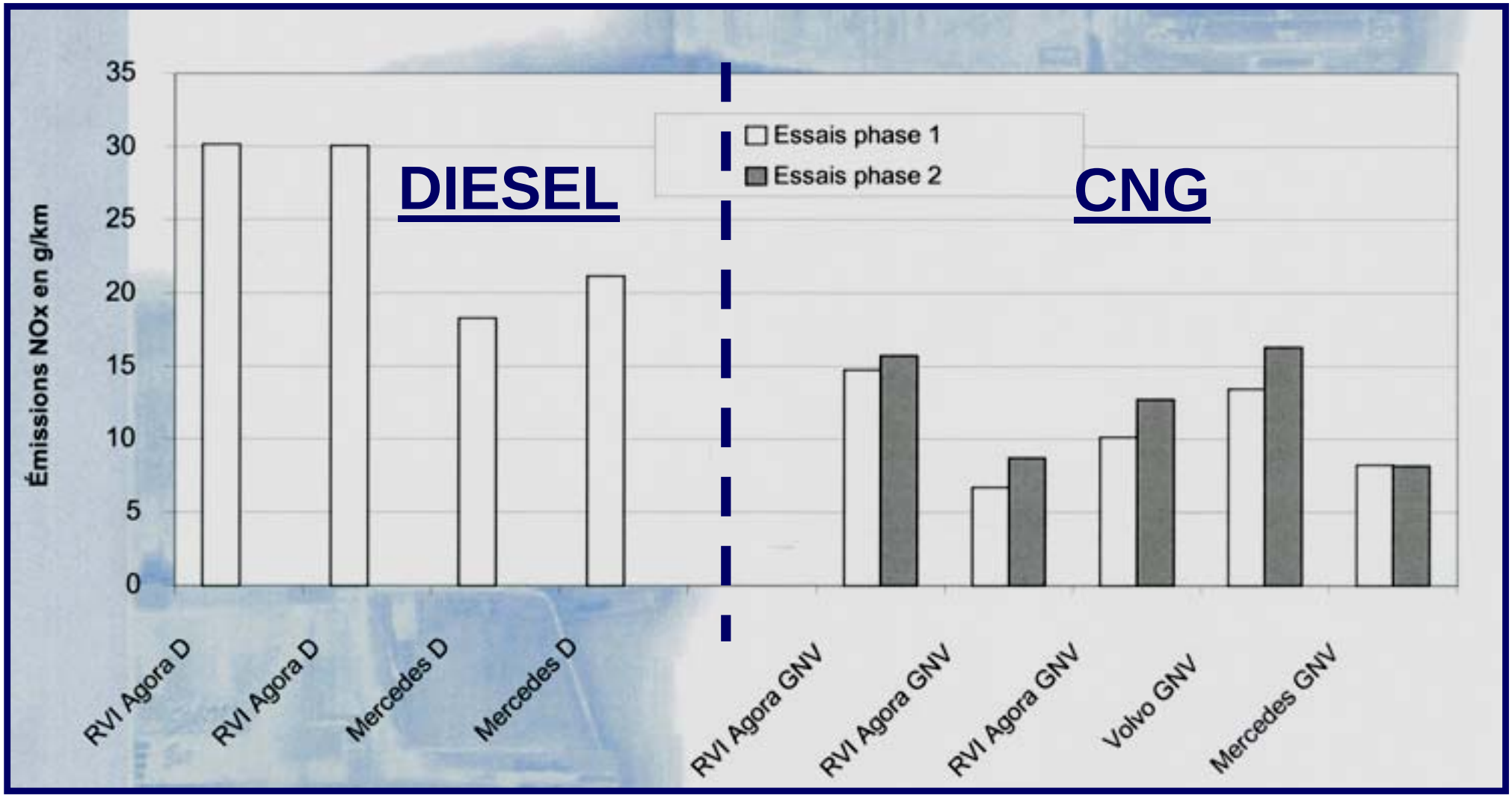
# CO Exhaust Emissions



# HC Exhaust Emissions



# NOx Exhaust Emissions

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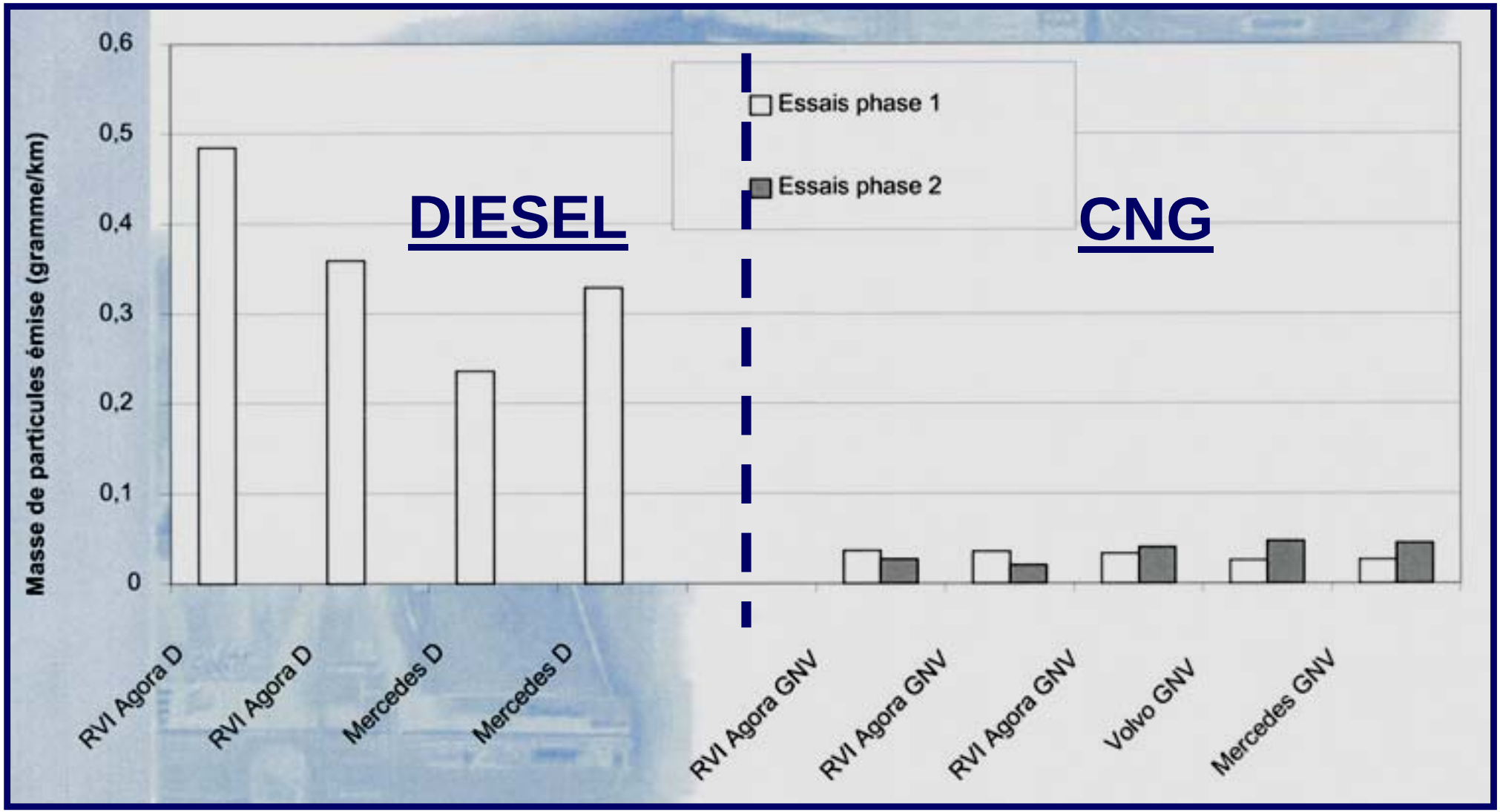
# PM Exhaust Emissions

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# 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)

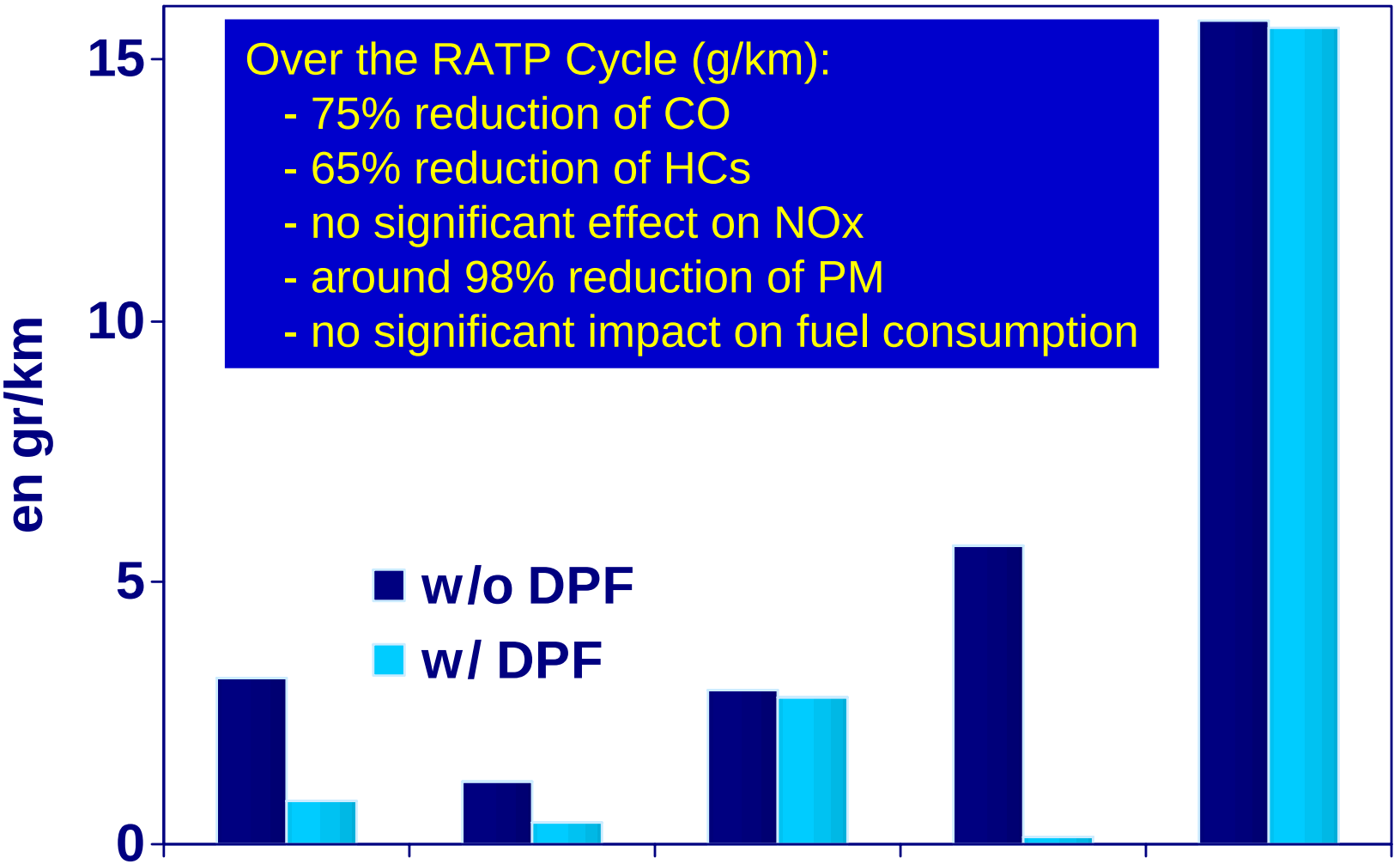
***after one year service,*** increase of aldehydes, regardless of CNG technologies, and heavy hydrocarbons (> C5)

- 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

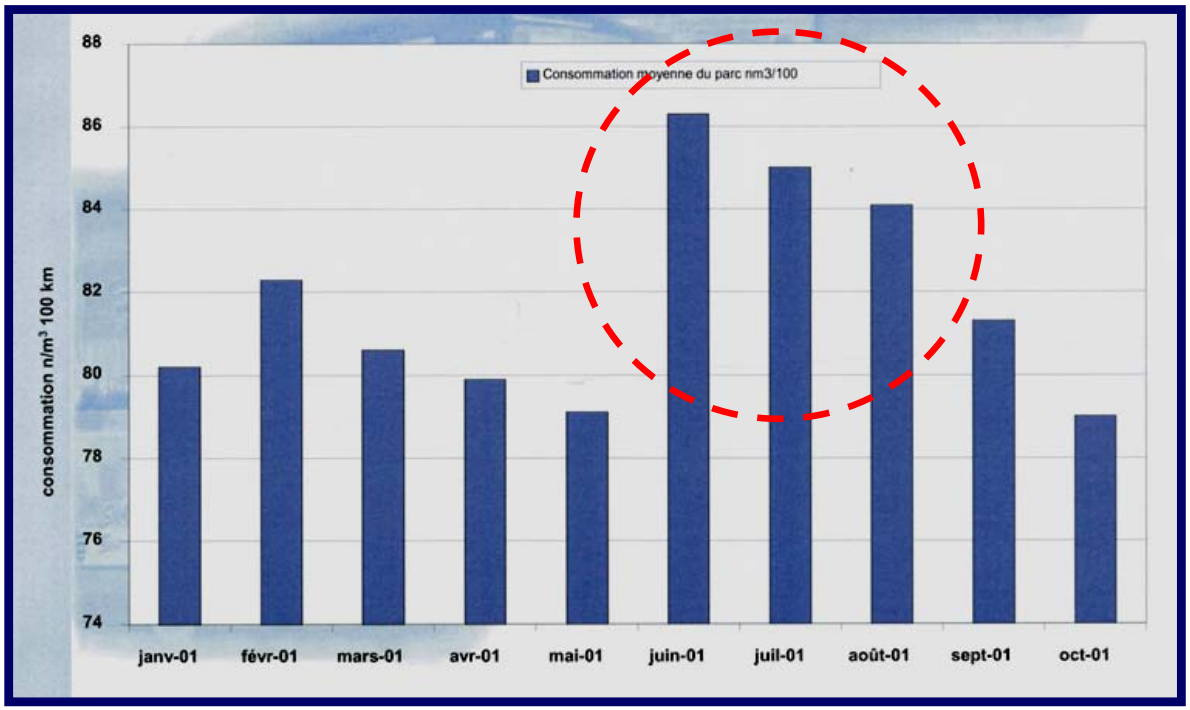


# CNG Consumption

***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

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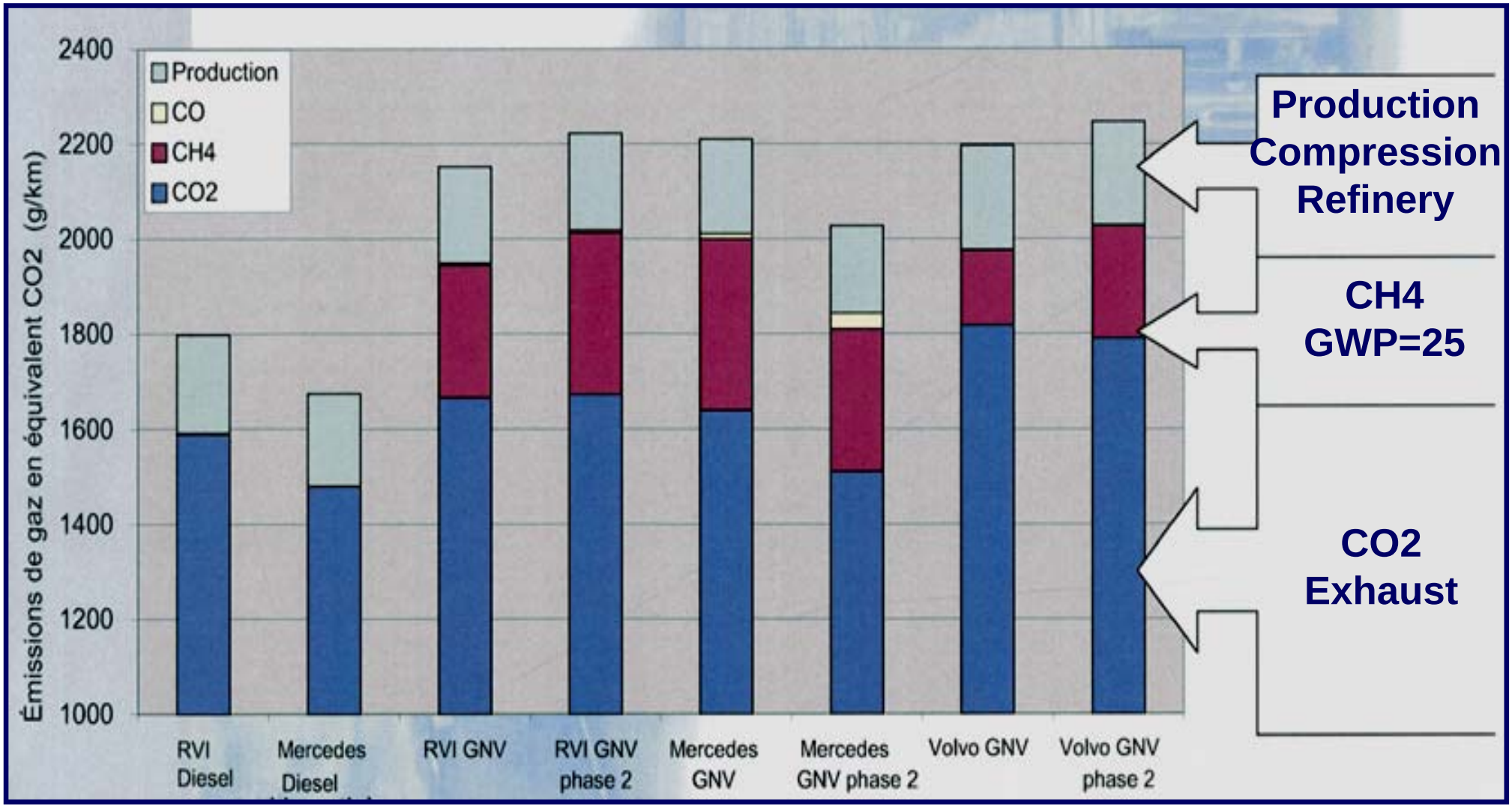
# Green House Gas Emissions

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# 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<br>- and compressed gas station:<br>450 to 500,000 € (investment) | Low Sulfur Fuel: 0,03 €/l |
| Security, Refilling speed, Maintenance (spark-plug, engine parts…) | - DPF regeneration machine (passive)<br>- DPF cleaning (60 to 100,000km)<br>- additional cost for Active DPF<br>- and NOx after-treatment |

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# 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*

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# Comparison trends & Summary

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

| Worse | - - | - | EURO 2 | + | + + | Better |
|---|---|---|---|---|---|---|

*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 $CH_4$ after-treatment
adapted maintenance
specific lubricant
combustion improvements (» $CO_2$ emission)
local organization (central compressed machine)

***Target:*** *20% CNG in Public Transports in Y2020*

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