CNG for cleaner cities and road transport

Alfredo Martín, January 2005
Fuel evolution in city / road transportation

Due to environmental and/or economic issues, the shift from liquid oil to gaseous fuels has begun in many countries.

- Low oil reserves
- Large gas reserves
- Population concentration in bigger cities
- Heavier needs of transport vs emission levels
- Poor city ventilation,

have made this growing shift quicker and wider
Advantages of CNG for city / road transportation

CNG fuel used in trucks and buses offers very significant advantages:

- Much lower gaseous emissions
- Much lower noise

In the case of stoichiometric mixture combustion (Iveco choice), exhaust pollutants are well below the levels of the EEV (Enhanced Environmental Vehicle), very near the fuel cell level.
NOISE EMISSION. Diesel vs CNG vehicles

- Diesel engine at 1 m.
- CNG engine at 1 m.

Sound levels:
- 70 dB (100-10000 Hz)
- 75 dB (100-10000 Hz)
- 80 dB (100-10000 Hz)
- 85 dB (100-10000 Hz)
- 90 dB (100-10000 Hz)
- 95 dB (100-10000 Hz)
- 100 dB (100-10000 Hz)

CNG for cleaner cities and road transport.
EMISSION AND FUEL CONSUMPTION VS AIR/FUEL RATIO

Optimum for 3 way catalyst adoption

Optimum for consumption/CO2

Combustion instability

Fuel consumption...

0.6 0.8 1 1.2 1.4 1.6 1.8

Rich Lean

0.6 0.8 1 1.2 1.4 1.6 1.8

Rich Lean
CNG – COMPARED EMISSIONS

COMPARED NOx EMISSIONS DIESEL vs ALTERNATIVE TECHNOLOGIES

- Diesel
- Euro 3
- Euro 4
- Euro 5
- CNG lean
- EEV limits
- Hybrid
- Fuel cell
- CNG IVECO stoich.
CNG – EMISSIONS

GASEOUS EMISSIONS IVECO 8469 ENGINE vs PRESENT AND FUTURE EUROPEAN LIMITS

- **CO (Carbon monoxide)**
- **NMHC (non-methane hydrocarbons)**
- **CH4 (mass of methane)**
- **NOx (nitrogen oxides)**
- **PT (particulates)**

**EURO 3 (2000)**
- CO: 5.45 g/kWh
- NMHC: 4 g/kWh
- CH4: 1.6 g/kWh
- NOx: 3.5 g/kWh
- PT: 0 g/kWh

**EURO 4 (2005)**
- CO: 0.54 g/kWh
- NMHC: 0.78 g/kWh
- CH4: 0.16 g/kWh
- NOx: 2 g/kWh
- PT: 0.02 g/kWh

**EURO 5 (2008)**
- CO: 0.55 g/kWh
- NMHC: 0.55 g/kWh
- CH4: 0.65 g/kWh
- NOx: 2 g/kWh
- PT: 0.03 g/kWh

**EEV**
- CO: 0.4 g/kWh
- NMHC: 0.04 g/kWh
- CH4: 0.18 g/kWh
- NOx: 1.18 g/kWh
- PT: 0.01 g/kWh

**IVECO**
- CO: 0.16 g/kWh
- NMHC: 0.03 g/kWh
- CH4: 0.02 g/kWh
- NOx: 0.01 g/kWh
- PT: 0.01 g/kWh

**Emissions [g/kWh]**

Data classification: Public
October 2004
IVECO CNG ENGINES

Natural Gas Business Development & Product Unit

Data classification: Public
October 2004
### REGULATED POLLUTANT EMISSION. VEHICLE IN OPERATION


<table>
<thead>
<tr>
<th>COMBUSTION MIXTURE TYPE</th>
<th>STOICHIOMETRIC</th>
<th>LEAN-BURN</th>
<th>IMPROV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC, g/km</td>
<td>1.17</td>
<td>1.92</td>
<td>39 %</td>
</tr>
<tr>
<td>NOx, g/km</td>
<td>2.17</td>
<td>4.50</td>
<td>52 %</td>
</tr>
<tr>
<td>PM, g/km</td>
<td>0.008</td>
<td>0.016</td>
<td>50 %</td>
</tr>
</tbody>
</table>

Stoichiometric Iveco engines, $\lambda=1$, don’t emit NO$_2$, the pollutant that doesn’t seem to be decreasing in Europe, on the contrary to NO that has a decreasing trend.

* VTT, Technical Research Centre of Finland, Transient Bus Emission Study  
** Braunschweig driving cycle
**CNG EXHAUST EMISSION COMPARISON (2)**

**CO2 EMISSION, GREENHOUSE EFFECT GAS (GHG) VEHICLE IN OPERATION**


<table>
<thead>
<tr>
<th>COMBUSTION MIXTURE TYPE</th>
<th>STOICHIOMETRIC</th>
<th>LEAN-BURN</th>
<th>IMPROV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂, g/km</td>
<td>1046</td>
<td>1447</td>
<td>28 %</td>
</tr>
</tbody>
</table>

(Diesel Euro 3, 1150 g/km 9 %)  
(Diesel Euro 3 + CRT, 1240 g/km 16 %)

**CO₂ EMISSION COMPARISON (% to DIESEL Euro3)**

<table>
<thead>
<tr>
<th>D. E 3</th>
<th>D. E 3+CRT</th>
<th>Lean-burn CNG</th>
<th>Stoich. GNC</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>108</td>
<td>126</td>
<td>91</td>
</tr>
</tbody>
</table>

* VTT, Technical Research Centre of Finland, Transient Bus Emission Study  
** Braunschweig driving cycle

Data classification: Public  
October 2004

IVECO  
Natural Gas Business Development & Product Unit
### CNG Iveco sales and running park (Europe)

<table>
<thead>
<tr>
<th></th>
<th>1999-2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAILY - TRUCK &amp; VAN</td>
<td>111</td>
<td>81</td>
<td>185</td>
<td>82</td>
<td>459</td>
</tr>
<tr>
<td>DAILY - IRISBUS</td>
<td>18</td>
<td>64</td>
<td>15</td>
<td></td>
<td>97</td>
</tr>
<tr>
<td>EUROTECH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1000</td>
</tr>
<tr>
<td>AUTOBUS IRISBUS</td>
<td>961</td>
<td>313</td>
<td>314</td>
<td>160</td>
<td>1827</td>
</tr>
<tr>
<td><strong>Final total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>3383</strong></td>
</tr>
</tbody>
</table>

The 1000 units of trucks are in:

- Spain: 550;
- France: 300;
- Italy: 150

**IVECO is the major player of CNG in Europe, and the clear leader in buses**
## IVECO CNG ENGINES LINE UP

<table>
<thead>
<tr>
<th>Model</th>
<th>Capacity</th>
<th>Type</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOFIM</td>
<td>2.8 l.</td>
<td>NA</td>
<td>106 CV</td>
</tr>
<tr>
<td>8460</td>
<td>9.5 l.</td>
<td>TC/TCA</td>
<td>218 to 310 CV</td>
</tr>
<tr>
<td>TECTOR</td>
<td>5.9 l.</td>
<td>TCA</td>
<td>200 CV</td>
</tr>
<tr>
<td>CURSOR</td>
<td>7.8 l.</td>
<td>TCA</td>
<td>270 / 310 CV</td>
</tr>
</tbody>
</table>

CNG for cleaner cities and road transport.
CURSOR F2G CNG ENGINE
IVECO DAILY CNG

Natural Gas Business Development & Product Unit

Data classification: Public
October 2004
EUROCARGO CNG

CNG for cleaner cities and road transport
## IVECO EUROTECH CNG

### Natural Gas Business Development & Product Unit

**Data classification:** Public

**October 2004**

### CNG. 4 x 2

**Suspensione Pneumatica**

<table>
<thead>
<tr>
<th>Modello - Model</th>
<th>Cabina - Cab</th>
<th>Passo - Wheelbase</th>
<th>Potenza - Power</th>
<th>Coppia - Torque</th>
<th>Cambio - Gearbox</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP190EI6P-CNG</td>
<td>MPC</td>
<td>3800 / 4200 / 4500 / 4800 / 5100</td>
<td>260 / 2100</td>
<td>1050 / 1100</td>
<td>D - O</td>
</tr>
</tbody>
</table>

### CNG. 6 x 2

**Asse Posteriore Sollevabile Sterzante**

<table>
<thead>
<tr>
<th>Modello - Model</th>
<th>Cabina - Cab</th>
<th>Passo - Wheelbase</th>
<th>Potenza - Power</th>
<th>Coppia - Torque</th>
<th>Cambio - Gearbox</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP240EI6P-CNG</td>
<td>MPC</td>
<td>3100 / 3800 / 4200 / 4500 / 4800 / 5100</td>
<td>260 / 2100</td>
<td>1050 / 1100</td>
<td>D - O</td>
</tr>
</tbody>
</table>

### CNG. 6 x 2

**Asse Posteriore Sollevabile Sterzante**

<table>
<thead>
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<th>Cambio - Gearbox</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP240EI6P-FP-CNG</td>
<td>MPC</td>
<td>4200</td>
<td>260 / 2100</td>
<td>1050 / 1100</td>
<td>D</td>
</tr>
</tbody>
</table>

### CNG. 6 x 2

**Asse Centrale Sterzante**

<table>
<thead>
<tr>
<th>Modello - Model</th>
<th>Cabina - Cab</th>
<th>Passo - Wheelbase</th>
<th>Potenza - Power</th>
<th>Coppia - Torque</th>
<th>Cambio - Gearbox</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP240EI6XPP-CNG</td>
<td>MPC</td>
<td>28/40</td>
<td>260 / 2100</td>
<td>1050 / 1100</td>
<td>Q</td>
</tr>
</tbody>
</table>

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CNG for cleaner cities and road transport
CNG Refuse collection fleet

Data classification: Public
October 2004

Natural Gas Business Development & Product Unit
IVECO CNG trucks for refuse collection in Madrid

CNG for cleaner cities and road transport

Data classification: Public
October 2004
IVECO CNG heavy trucks for refuse collection in Europe

CNG for cleaner cities and road transport

Data classification: Public
October 2004
IRISBUS – AUTOBUS CNG

EUROPOLIS CNG

ZAMYAD BUS A60.11
(MOTORE 8149)

CITY CLASS CNG 12 and 18 m

BEIJING BUS TECTOR CNG

Data classification: Public
October 2004

Natural Gas Business Development & Product Unit
CNG BUS FLEET IN MADRID

Natural Gas Business Development & Product Unit

Data classification: Public
October 2004
IVECO CNG urban buses in Madrid

Data classification: Public

Natural Gas Business Development & Product Unit

CNG for cleaner cities and road transport

October 2004
The refuse collection company FCC S.A., operating basically in Madrid but with other locations world wide, has acquired about 320 CNG units since 1999 with a yearly average mileage of 55,000 km.

In the public transport sector there are other companies such as EMT Madrid, TMB Barcelona, ATAF Florence and ATM Ravenna, with 114, 105, 91 and 8 CNG buses respectively with a yearly average mileage between 45,000 and 60,000 km.

In each of these companies there are vehicles that have already shown a good performance in the long term:

<table>
<thead>
<tr>
<th>TOWN</th>
<th>MISSION</th>
<th>YEAR</th>
<th>TOTAL KM/UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MADRID</td>
<td>BUS</td>
<td>1998</td>
<td>320,000</td>
</tr>
<tr>
<td>MADRID</td>
<td>REFUSE COLLECTION</td>
<td>1999</td>
<td>241,000</td>
</tr>
<tr>
<td>BARCELONA</td>
<td>BUS</td>
<td>2001</td>
<td>130,000</td>
</tr>
<tr>
<td>FLORENCE</td>
<td>BUS</td>
<td>1998</td>
<td>280,000</td>
</tr>
<tr>
<td>RAVENNA</td>
<td>BUS</td>
<td>1998</td>
<td>350,000</td>
</tr>
</tbody>
</table>

TOTAL HEAVY CNG FLEET MILEAGE, >353,000,000 KM
IVECO-OTOYOL CNG BUS FOR IRAN

3,000 UNITS FORESEEN FOR THE NEXT 3 YEARS
IVECO PORTFOLIO OF ORDERS FOR CNG VEHICLES AND ENGINES:
MORE THAN 2.800 UNITS
CONCLUSIONS

• CNG VEHICLES CONSTITUTE AN ECONOMIC, UP-TO-DATE AND DEPENDABLE ALTERNATIVE TO DIESEL VEHICLES, TO IMPROVE ACOUSTIC AND GASEOUS EMISSIONS SIMULTANEOUSLY

• ADDITIONALLY, CNG IVECO VEHICLES, WITH STOICHIOMETRIC COMBUSTION, PROVIDE EVEN BETTER POLLUTION AND CO₂ EMISSION LEVELS.

• TODAY IVECO OFFERS A RANGE OF CNG VEHICLES COMPLYING WITH THE E.E.V. STANDARD AND CONTINUES DEVELOPING STATE-OF-THE-ART CNG VEHICLES TO SATISFY GLOBAL MARKET NEEDS.