

## **Position Paper: Natural Gas and CO<sub>2</sub>** **Natural gas is a champion in road transport and also saving CO<sub>2</sub> emissions**

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### **1. Foreword**

The main environmental concern has changed in the last few years.

At the beginning of the decade the main issue was “local pollution” in cities. This concern gave rise to a very significant effort by all the concerned parties; apart from organizational measures (congestion charges, traffic restrictions etc.), in the technical field the “Euro” emission limits were issued and restricted, and the engine and vehicle manufactures succeeded in designing and delivering better products, so that nowadays it is generally assumed that the pollution due to road transport is no more a main issue, and that further improvements will have little environmental effect in exchange for an unreasonable cost.

As for “local pollution” it was always considered without doubt that the choice of natural gas was the best one.

But now the concern has strongly shifted to global warming and more in general to energy consumption, the emission of CO<sub>2</sub> being held mainly responsible for the “greenhouse effect”.

In road transport, especially for heavy-duty vehicles, natural gas has to compare with diesel, natural gas has the wrong reputation of giving off higher CO<sub>2</sub> emissions.

The purpose of this paper is to dispel the abovementioned false statement. Engine technology has evolved in such a way so that natural gas is the least CO<sub>2</sub> emitting fuel among the ones used (and usable) today.

## CO<sub>2</sub> is not a “pollutant”. It is a consequence of energy generation

Human beings produce CO<sub>2</sub> as a result of their living (about 0.75 kg per day). An urban bus produces 300 kg per day, exactly as much as 400 people. “Local pollutants” (nitrogen oxide, particulates, etc.) can be reduced to zero in a perfect engine, while CO<sub>2</sub> exists in that it strictly depends on fuel consumption, being the result of combustion (combination with oxygen). Different fuels contain different amounts of carbon, and therefore produce different amount of CO<sub>2</sub> per unit energy consumed, see the following table:

Fuel	H/C Ratio	g CO <sub>2</sub> per MJ fuel	%
Gasoline, diesel fuel	1.85:1	73	100
LPG (50 propane/50 buthane)	2.52:1	66	90
Pure methane CH <sub>4</sub>	4:1	56	77
Blend CH <sub>4</sub> +30%H <sub>2</sub>	4.86:1	50	68
Pure hydrogen	---	---	---

Compared to diesel fuel or gasoline, natural gas (methane) produces 23% less CO<sub>2</sub> per unit energy.

## 2. Burn the fuel efficiently: CO<sub>2</sub> “from tank to wheel (TTW)”

The acronym TTW has become familiar to express the energy pathway within the vehicle. The amount of CO<sub>2</sub> emitted in this process depends on the efficiency of the prime mover and of the driveline.

The spark-ignited engine (Otto-cycle) has approximately the same efficiency if running on gasoline or on natural gas, and therefore, the use of natural gas reduces CO<sub>2</sub> emissions by one quarter. (In principle, the gain would be even more if the engine was optimized for natural gas, but we are considering the case of bi-fuel vehicles).

On the other hand, when it is a matter of comparing a diesel engine with a natural gas spark engine the comparison becomes very interesting, since in principle the diesel engine has some

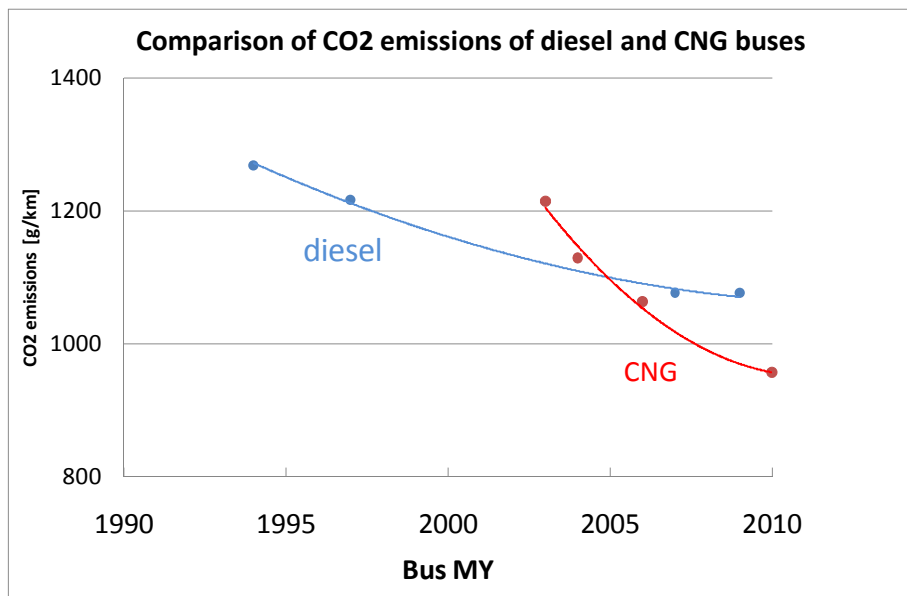
20-25% higher efficiency than the spark-one, thus covering the difference in CO<sub>2</sub> emission between the two fuels.

We will deal with this case in some length, since the matter is very interesting for urban buses application.

The emission comparison of urban buses running on diesel or on natural gas has been the object of several very deep experimental investigations run by primary international research institutes, as VTT in Finland (1) (2) (3) and FVT- Graz in Austria (4)

These investigations are very extensive, running from Euro I to EEV buses, both diesel and NGV.

From the whole of the investigations, the chart reproduced hereafter can be drawn. That refers to the CO<sub>2</sub> emitted by different buses on the standardized “Braunschweig” cycle, which is very common for these kinds of investigations, so that a wide data bank is available.



Diesel technology: the above chart shows a diesel technology that had a significant increase in efficiency (and therefore decreases in CO<sub>2</sub> emissions) in the nineties, in spite of the ever increasing stricter emission requirements: and this was made possible by the introduction of very sophisticated electronic injection equipment and engine control, and variable turbocharging control. In the year 2000, with the advent of Euro IV, Euro V and EEV, the catalysts came into play also for diesel engines (like what happened 15 years before with gasoline engines), and the efficiency reached a sort of “asymptote”, corresponding to 1100 g/km of CO<sub>2</sub>.

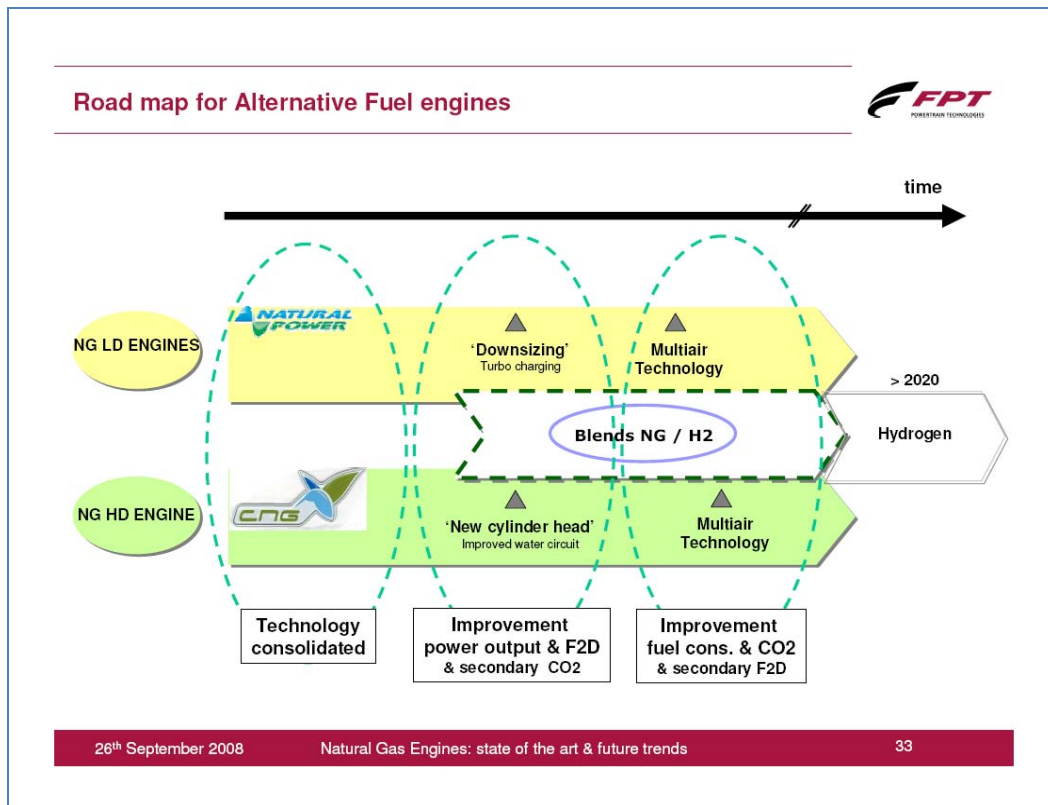
Today, an EEV diesel engine has a very complex catalyst for NOx and particulates (SCRT) so that somebody says: “... looking into the future, self ignition vehicles will turn into chemical plants for exhaust gas treatment instead of mobility providers.”

Looking once more at the chart above, CNG technology appears to be a “younger” technology, with a faster efficiency increase. In fact, the first generation of CNG engines around the year 2000 were derived from the corresponding diesels with the minimum of investments, waiting for the market to expand, and therefore, they were not optimized from the point of view of efficiency.

More recently, a second generation of CNG engines appeared, diffusing the “stoichiometric concept” and the engine components were optimized for the fuel used (ex.: cylinder heads with more efficient cooling).

Today the situation is that diesel and CNG have roughly the same CO<sub>2</sub> emissions. (“Somewhat surprisingly, the lowest CO<sub>2</sub> emission was recorded for the stoichiometric EEV CNG vehicle. On average, CRT diesel and CNG gave roughly equivalent CO<sub>2</sub> emissions”). (1)

However, CNG technology still has a card up its sleeve. In fact, at the recent (Sept.2008) Fair of NGVs in Torino, Fiat presented the development scenario that is reproduced hereafter:



One can see that for the future of CNG engines “Multi-air” technology is ready to be adopted, consisting of a special hydraulic drive of the intake valve (early closing or partial opening), that significantly reduces the power losses across the butterfly of the spark engine. A further efficiency increase of 7-10% is expected, and that makes the NGV CO<sub>2</sub> line of the previous page “sink” well below the diesel line for 2010.

Definitely, Natural Gas has the least fuel emissions in the “Tank to Wheel” process.

### **3. Bring the fuel to the vehicle: energy and CO<sub>2</sub> “from well to tank (WTT)”**

The process of bringing fuel to the vehicle is extremely complicated, as it involves Extraction, Processing, Transport and Storage of the raw fuel (ex.: crude oil) and Production, Transport, Storage and Distribution of the refined fuel.

Limiting our comparison to diesel fuel/natural gas, it appears that the natural gas path is much simpler, as the “raw” fuel needs no refining, and the distribution occurs, at least for the majority of European countries, through the “domestic” distribution grid. It is therefore evident that in this path also Natural Gas requires less energy.

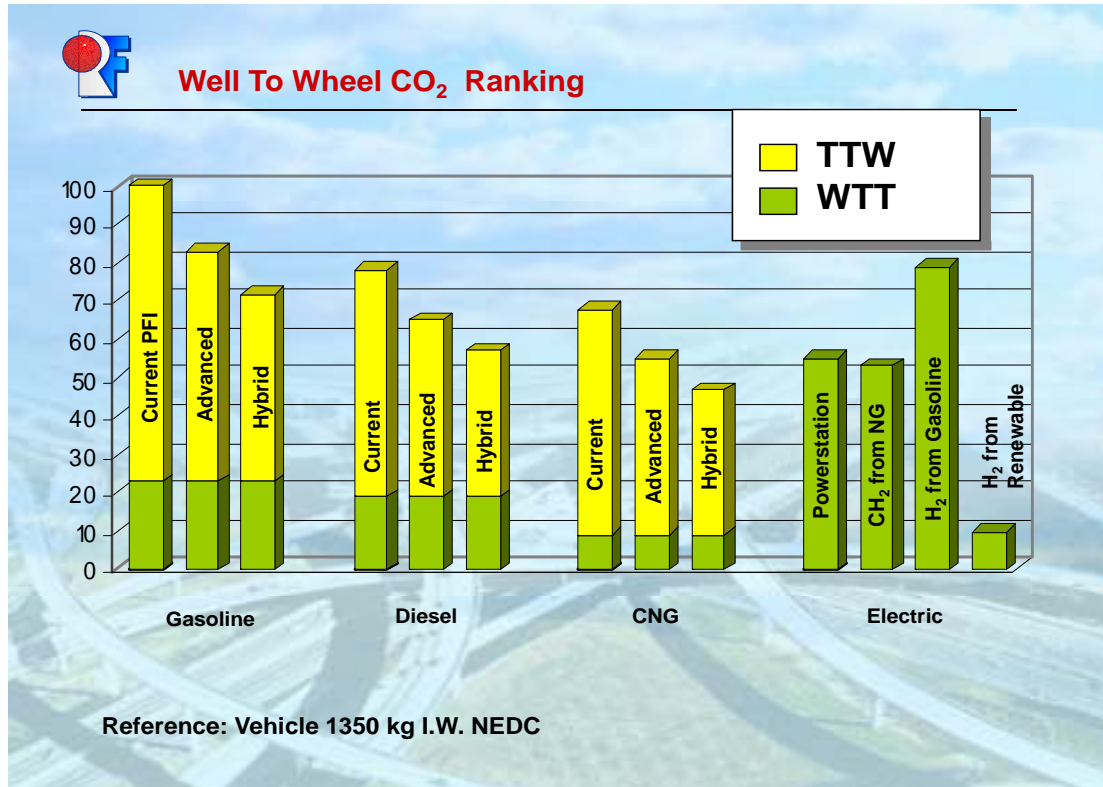
### **4. Overall balance “Well to wheels (WTW)”**

Thus we come to the overall process (Well to Wheel = Well To Tank + Tank To Wheel).

This matter has been, and is, the subject of very complicated and sophisticated studies and calculations of energy consumption and emissions of the WTW path, in order to find hints and indications for the best fuels and powertrains for the following decades.

We will quote a study supported by Concaawe, JRC and Eucar, first started in 2003, and being continuously updated and expanded , version 2c published in 2007 (5), version 3 in preparation, see JRC website.

Without going into such complicated details, we reproduce here a figure, presented some years ago (6), but still fully valid, which depicts in a simple way the clear advantage of natural gas. Only hydrogen obtained by electrolysis from renewable sources has lesser CO<sub>2</sub>



Current: technology of 2005

Advanced: Technology of 2010

Hybrid: Hybrid powertrain configuration

NOTE: Sometimes reference is made, more than to CO<sub>2</sub>, to the so-called "Global Warming Index"(GWI) where (7) :

$$GWI= CO_2 + 23*CH_4 + 296*N_2O$$

would be the quantity responsible for the greenhouse effect. Since the amount of methane, even in the case of a CNG engine, is very small, even if the methane emission was multiplied by a factor of 23 and added to the CO<sub>2</sub> emission value to describe total greenhouse gas effects, this would not have changed the outcome of the comparison. (1)

## 6. Conclusions

The main concern of environmental protection has shifted in recent years from “local pollution” (Nitrogen Oxide, Particulates) to the emission of greenhouse gases, mainly CO<sub>2</sub>.

From the discussion that the gasoline spark-ignition engine has a higher level of CO<sub>2</sub>, the two viable fuels today, especially for heavy duty road propulsion are diesel fuel and compressed natural gas.

Powerlines fed by these two fuels have today roughly the same CO<sub>2</sub> emissions, but while diesel technology seems to have reached an “asymptote”, spark ignition technology has still some improvements to make, that will bring its CO<sub>2</sub> emissions, in the near future, to mean some 10% less than diesel.

In addition to that, natural gas has the way open to bio-methane, that is essentially a greenhouse-free fuel, and to the blends of methane with hydrogen, that is carbon-free.

Perspectives that are not so far in the future.

This NGVA Europe Position Paper has been written by Renato Gaudio & Ezio Volpi

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