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Evaluation of environmental improvements of a post-market dual-fuel kit for heavy duty vehicles

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Background

Air quality is a major concern in developed Countries. Emissions from diesel combustion are considered one of the most important sources of alteration of air quality especially in those regions where goods transport is performed preferentially by heavy and light diesel trucks and in most of highly populated European cities. The North of Italy, and in particular the Po Valley region, is one of the most polluted area in EU (Pira and Piolatto, 2013) although the efforts of the local authorities to reduce particulate matter (PM) and other gaseous pollutants concentrations in the atmosphere, such as nitrogen oxides (NO_x). In Lombardy Region diesel contributions to fine PM ($PM_{2.5}$) account for 19% (INEMAR, Arpa Lombardia, 2010). As a consequence actions aiming at the reduction of primary emissions from diesel engines, and especially from trucks Euro 4, and earlier Euro, are of primary interest.

Material and methods

A commercial diesel Euro 3 heavy duty truck was equipped with a post market kit for dual-fuel, diesel-natural gas, propelling. On road experiments were performed to evaluate preliminary data of the emission levels and fuel consumption of the modified truck (see table 1). These data were used in primary approximation to evaluate the maximum theoretical feasible reduction (MTFR), i.e. the reduction of air pollutants (PM_{10} and NO_x) considering the maximal (100%) implementation of the proposed system. MTFR considers the application of the kit on all diesel trucks, heavy, light duty and buses, circulating in Italy, and it is evaluated running the model GAINS-Italy defining as time horizon the year 2020 (for detail on GAINS-Italy see: D'Elia et al, 2007, Italian version of the well-known GAINS model http://gains.iiasa.ac.at). The MTFR results where then compared to a reference scenario (CLE) in which the Italian National Energy Strategy and all the national initiatives aiming at the reduction of air pollutants emission from other sectors than Energy were modelled.

Table 1 – Emission factors and fuel consumption from "on road" tests

Fuel / Emission factor	Diesel	Dual-fuel	Rate of reduction
NO_x (g/kWh)	2,293	id	0
PM_{10} (g/kWh)	0,057	0,031	46%
CO_2 (g/km)	1078	1027	4,7%
Consumption Diesel (l/100km) NG (kg/100km)	40,0	25.3 12,2	37%

Results

Data from "on road" tests show that the main reduction achievable is the abatement of PM10 emissions while minimal or no improvements are expected for CO_2 and NO_x (Table 1). These data were used as input in GAINS-Italy and the modelling showed that the main result is an overall reduction of PM_{10} considering all the emission from the transport sector (Fig 1). The main reduction in PM emission is expected for the category "Light duty" (-34%) followed by "Heavy duty" (-22%) and "and "Bus"(-20%). The emissions from "Cars" is not affected accordingly to the hypothesis of this study.

However, considering total PM_{10} emissions estimated for all the possible sources at the time horizon 2020, the overall impact of the kit account for a maximal theoretical reduction of 2% with total emission decreasing from 179.40 Kton in CLE to 175.67 Kton in MTFR (Table 2).
Considering the different Euro vehicles class expected to circulate in 2020 the major contributors to total PM emissions will be vehicles Euro 0.

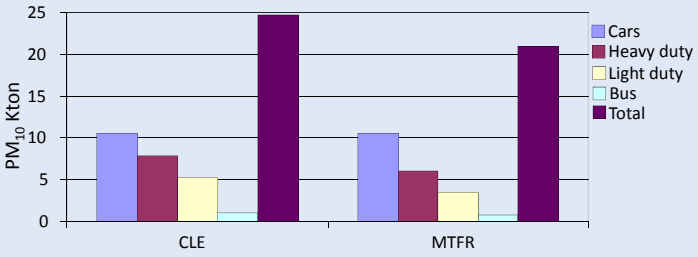

Figure 1 – Emission of PM_{10} at the horizon 2020 in reference condition (CLE) and considering the maximal theoretical application of the kit (MTFR)

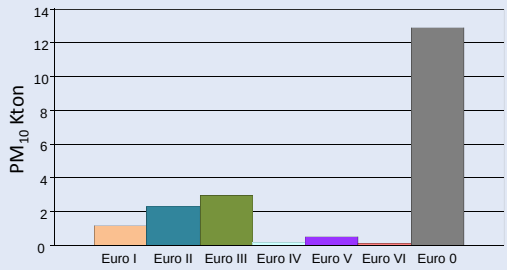

Figure 2 – Emission of PM10 at the horizon 2020 distributed among the different Euro class for vehicles

Given the rates of reduction (Table 1), the impact of the kit on the abatement of CO_2 emission is relatively low. For sector "Road transport" the percentage of reduction obtainable is 1,98% which represents the 0,48% of total CO_2 expected in Italy in 2020 (Table 2).

Table 2– Emissions of PM_{10} and CO_2 at 2020: comparison between reference condition (CLE) and maximal theoretical feasible reduction (MTFR)

	PM_{10} (Kton) Road transport	PM_{10} (Kton) Total	**CO_2 (Kton) Road transport**	CO_2 (Kton) Total
CLE emission 2020	24.75	179.40	111.86	459.74
MTFR emission 2020	21.03	175.67	109.65	457.52
Reduction expected	15%	2%	1.98%	0.48%

Conclusions

- GAINS-Italy is a useful tool for modelling future national scenarios of air pollutant emissions from new combustion technologies
- The retrofit kit analysed in this case study determines a reduction of diesel consumption and pollutants emission (CO_2 and PM)
- PM is reduced of 15% in road transport sector which accounts for the 2% of total PM emissions expected in Italy in 2020 (MTFR)
- CO_2 reduction accounts for 2% in road transport sector in relation to partial substitution of diesel oil with natural gas
- The results suggest that heavy duty vehicles with retrofit kit for dual-fuel combustion may be considered as an additional strategy for PM emissions abatement

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