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Laboratory and on-road tests assessment of fine and ultrafine particle emission factors for Euro 6 LPG passenger cars

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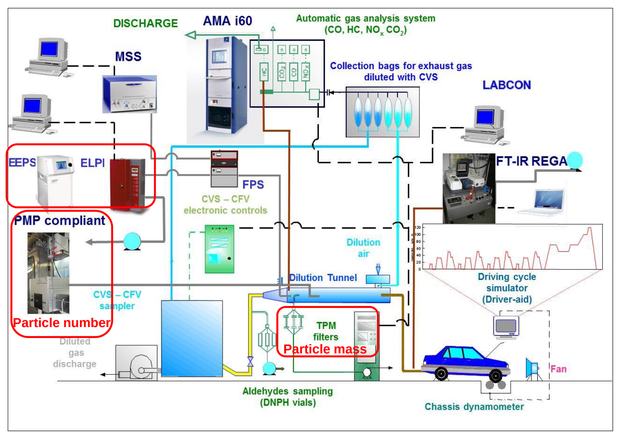
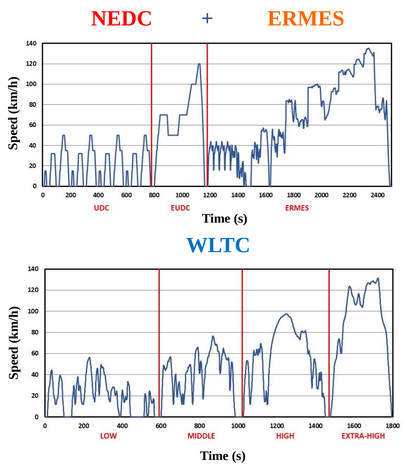
Background

- Liquefied petroleum gas (LPG)-gasoline bi-fuel passenger cars are a relevant share of the circulating fleet in some countries
- Italy has the second-largest circulating fleet (about 2.6 millions of vehicles) of LPG passenger cars in the European Union after Poland and the sixth-largest in the world
- Original equipment manufacturers (OEMs) bi-fuel vehicles, and conventional gasoline vehicles later retrofitted to operate with LPG accounted for 6.7% of the Italian passenger cars circulating fleet in 2020, 29.5% of these with Euro 6 homologation
- Updated emission factors (EFs) were not available for Euro 6 LPG passenger cars in the COPERT software, the standard vehicle emissions model developed for official road transport emission inventory compilation in EU member countries
- Italian country-specific EFs for Euro 6 passenger cars have been calculated based on data from both laboratory and on-road emission tests performed on a pool of five Euro 6 LPG bi-fuel passenger cars representative of the different technologies of the circulating Italian fleet

Material and methods

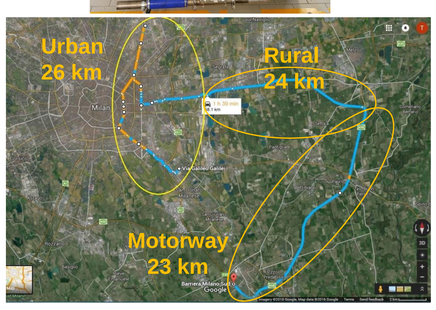
Laboratory tests





- Chassis dynamometer tests in a test cell (T = 23 ± 3 °C; RH = 50 ± 5 %)
- Tests with NEDC, WLTC, and ERMES (hot start) driving cycle
- 3 NEDC, 3 ERMES, and 1 WLTC test for each fuel and each car
- Measurements for regulated particle mass (PM) and solid particle number (PN-PMP compliant, 23 nm-2.5 µm range), and non-regulated particle number (PN-ELPI, 7 nm-10 µm range; PN-EEPS, 5.6-560 nm range)

On-road tests



- On-board system for PN (>23 nm) through a volatile particle remover followed by a diffusion charger detector
- 2 tests for each fuel and car

Test cars

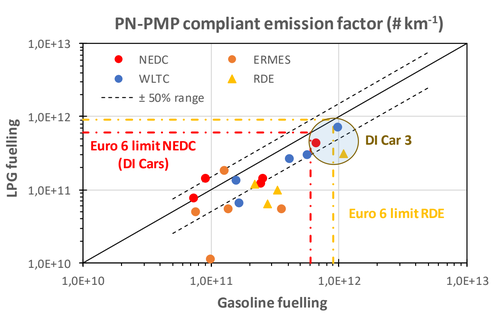
	Car 1	Car 2	Car 3	Car 4	Car 5
EURO class	Euro 6b	Euro 6b	Euro 6b	Euro 6b	Euro 6c
Type approval driving cycle	NEDC	NEDC	NEDC	NEDC	WLTC
Engine capacity [cm^3]	1248	1598	1197	1590	1598
COPERT segment	Small	Medium	Small	Medium	Medium
Injection type	PFI	PFI	DI	PFI	PFI
LPG powertrain	Retrofit	Retrofit	Retrofit	OEM	OEM

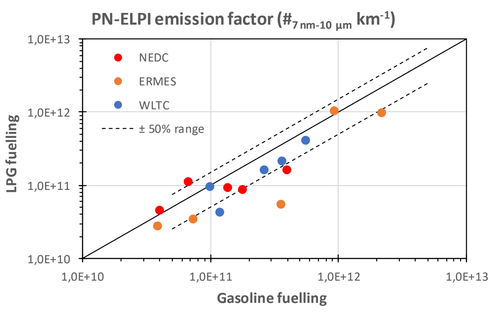
PFI = Port Fuel Injection; DI = Direct Injection

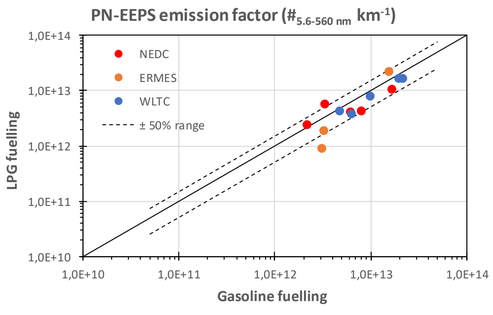
- Test cars from different manufacturers
- Separately tested with both commercial gasoline and LPG
- On LPG tests car engines always started-up in gasoline mode, automatically switching to LPG after 1-2 minutes

Results

Emission factors

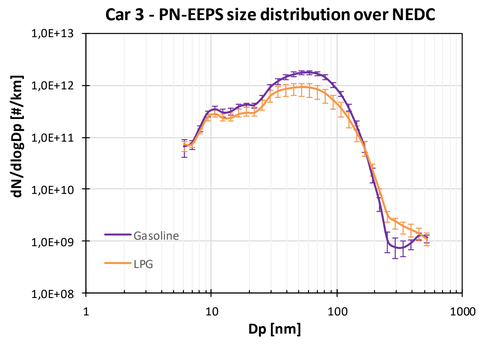


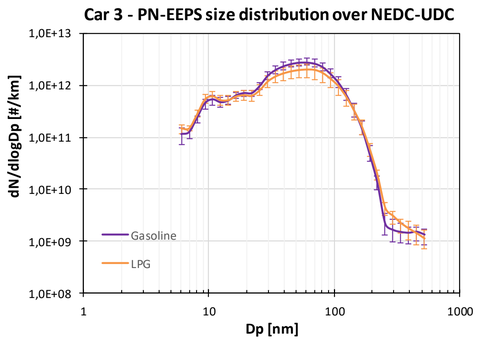


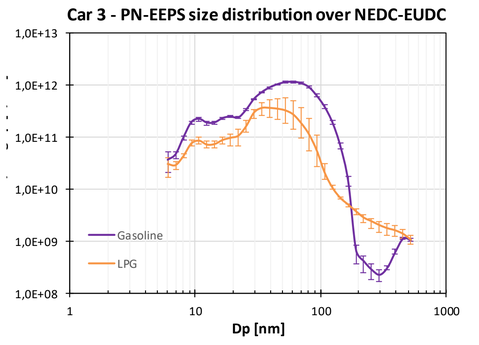


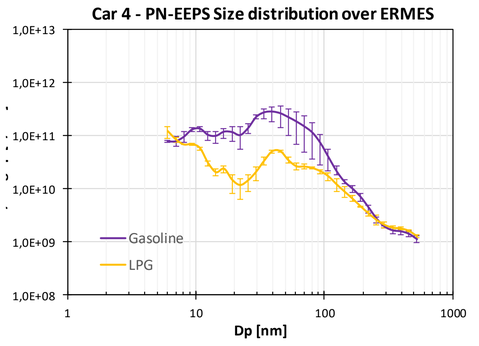
- Low PM emissions measured for all the tested cars and for both the fuels (0.005-0.426 mg/km range), well below the Euro 6 NEDC limit (4.5 mg/km); no statistically significant variations detected between gasoline and LPG fuelling
- Euro 6 limit PN-PMP compliant respected only for LPG fuelling over the NEDC (only applied to Car 3): limit exceeded (+10.9%) over the NEDC (6.65E+11 #/km vs. 6.0E+11 #/km) and (+17.2%) over RDE (1.05E+12 #/km vs. 9.0E+11 #/km) for gasoline fuelling
- Generally lower emissions with LPG fuelling. Overall mean reductions (± mean st. dev.): 34.4% (±10.2%) for PN-PMP compliant, 32.4% (±9.5%) for PN-ELPI, 17.8% (±9.1%) for PN-EEPS in laboratory tests; indicatively, up to around 70% reduction for PN in RDE tests
- LPG fuelling resulted in statistically significant reductions (Welch's t-test, α = 0.95) of PN-PMP compliant emissions only for Car 3 over NEDC (36.5%) and Car 1, 3, 4 over ERMES (36.2%, 85.6%, 89.8%); likewise, significant reductions also observed for PN-ELPI and PN-EEPS
- Similar PN-EEPS size distributions over the whole NEDC, but marked difference over NEDC-EUDC and over ERMES in the 10-100 nm range

Size distributions (cars with statistically different PN-EEPS)









Conclusions

- A pool of five Euro 6 (B and C) LPG bi-fuel passenger cars was tested over several driving cycles (NEDC, ERMES, WLTC) and on road (RDE) on both gasoline and LPG fuelling.
- Switching from gasoline to LPG both in laboratory and on-road tests showed reduced particulate emissions and different size distributions, especially during the hot phases of the driving cycles
- PM and PN emission factors for LPG fuelling were calculated and made available at Italian and international level for updating EFs databases of emission models

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