Experimental investigation of ethanol-gasoline dual-fuel on particle emissions at the exhaust of a small displacement engine

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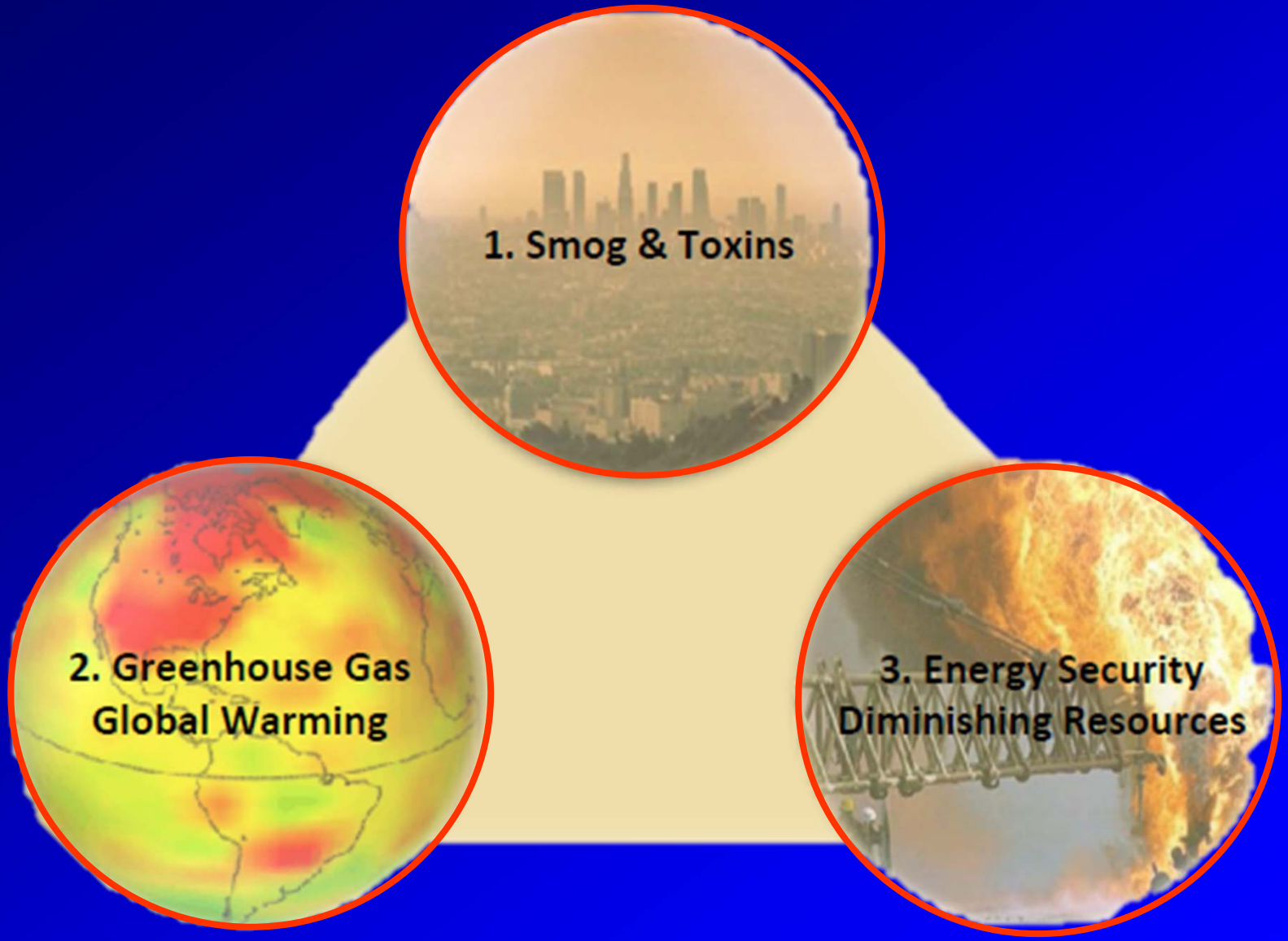
18th ETH
Conference on Combustion Generated Nanoparticles

Main concerns on transportation



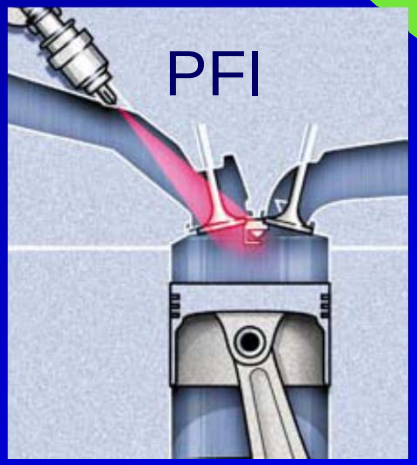
Introduction

Carbon footprint

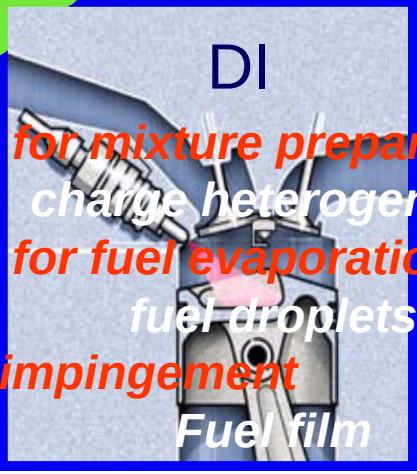
Fuel economy

Lowest pollutant emissions

Engine performance

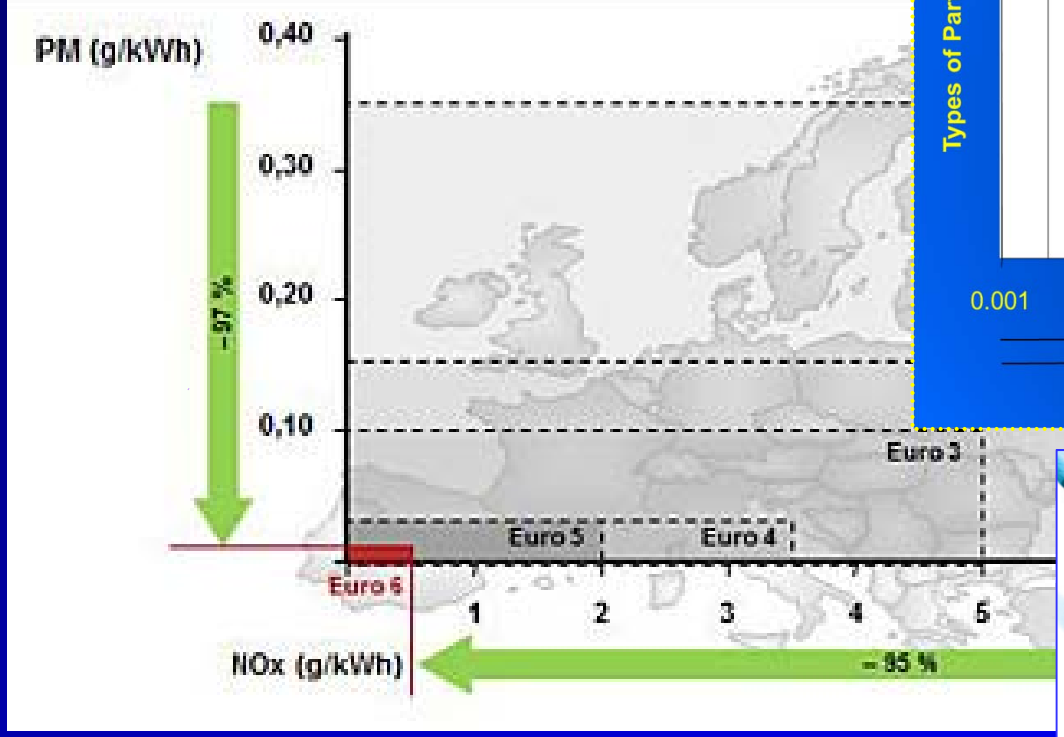


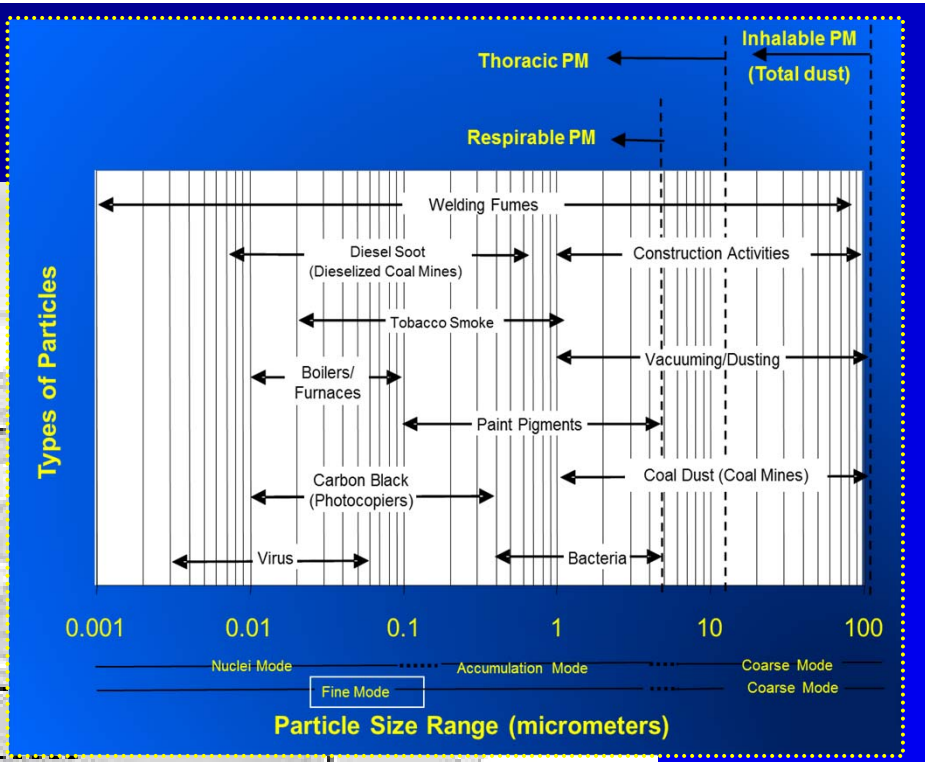
Increase of PM emissions

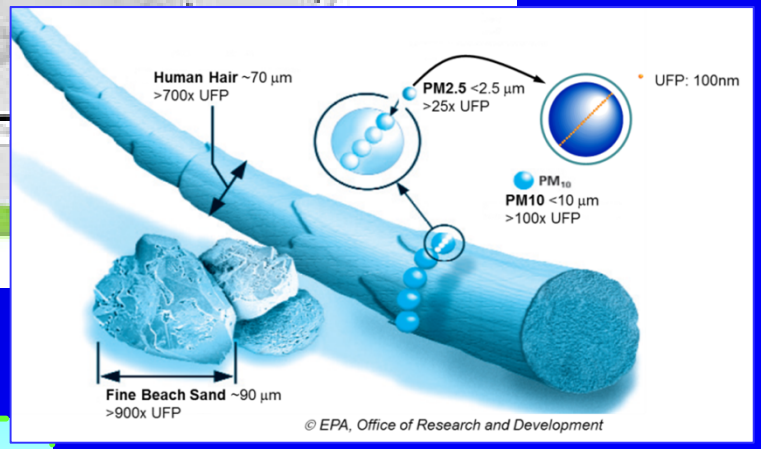


Time for mixture preparation:
charge heterogeneity
Time for fuel evaporation
fuel droplets
Wall impingement
Fuel film

Emission regulation Euro 6







PN regulation

6.0×10^{12} 1/km of particles smaller than 23 nm

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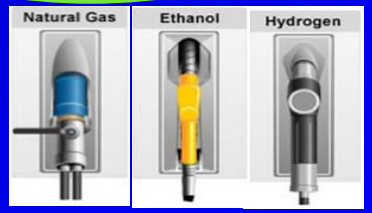
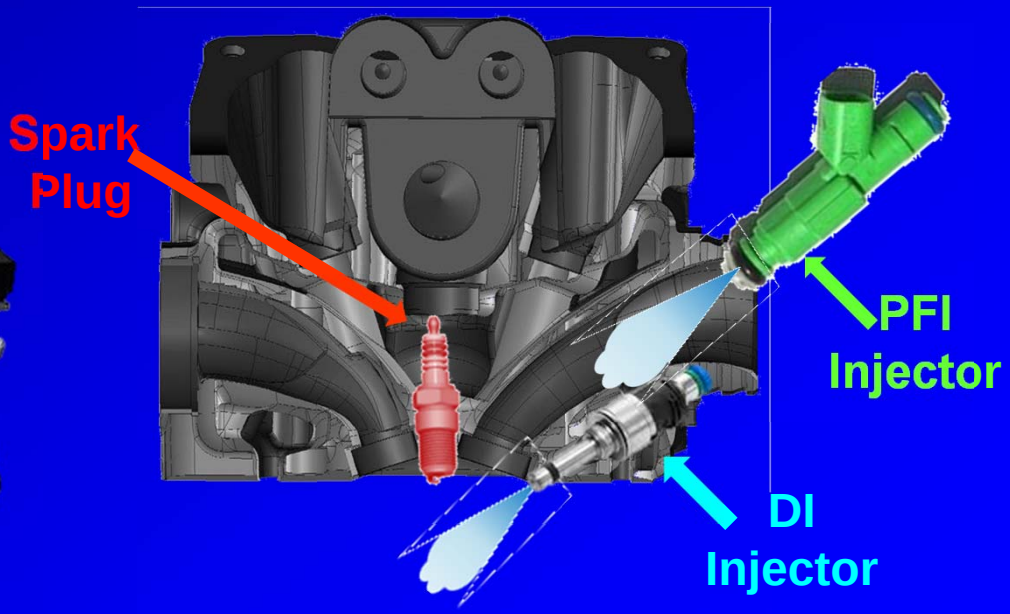


Octane enhancer
Oxygenated fuel

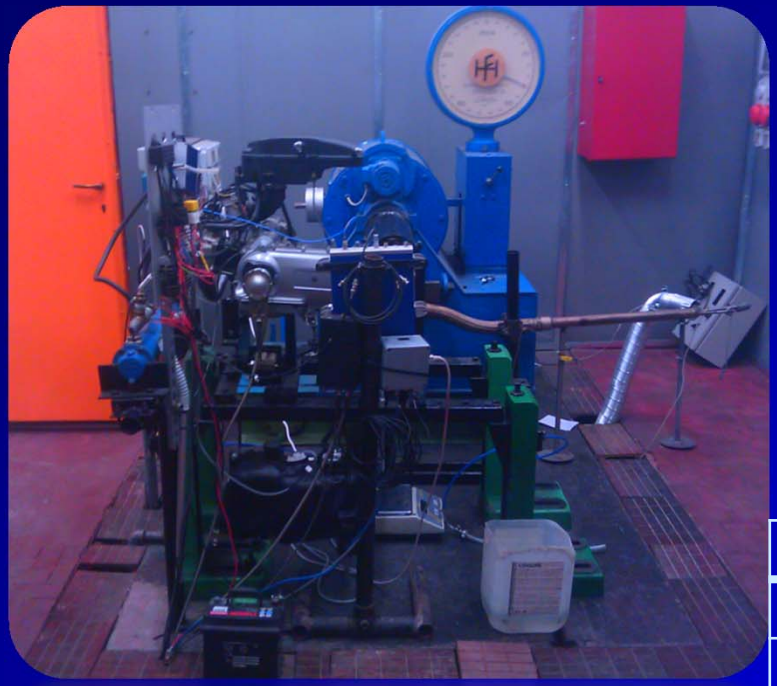
Objective

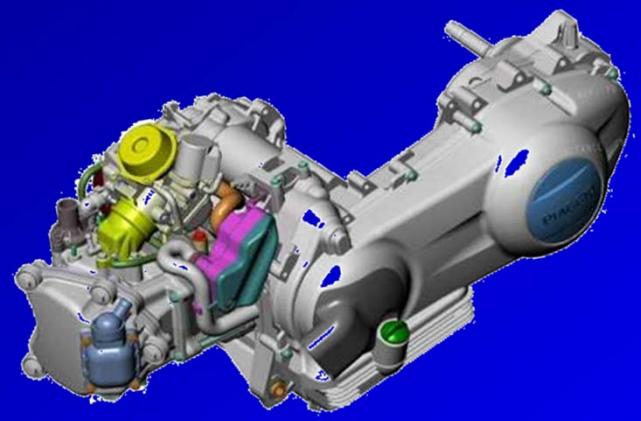
Characterization of particle emissions from ethanol/gasoline dual fueling engine

Gasoline: Port Fuel Injection
Ethanol: Direct Injection



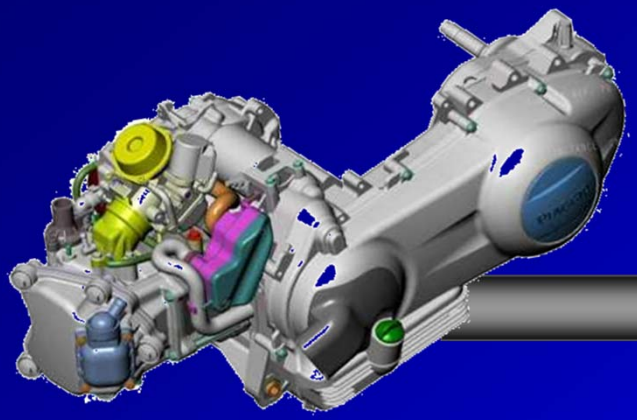
SI Engine





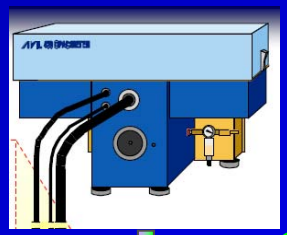
Engine type	4-stroke single cylinder	
Displacement (cm^3)	250	
Bore (mm)	72	
Stroke (mm)	60	
Engine size (cm^3)	522.1	
Bowl Volume (cm^3)	19.7	
Maximum Torque [Nm]	20 Nm @ 5500 rpm	
Maximum Power [kW]	16 kW @ 8000 rpm	
Compression ratio	10.5:1	
Injector Type	PFI Commercial	DI Prototypal
Number of Nozzle Holes	3	6

Experimental Layout



Smoke meter

Opacimeter



DEED

EEPS

Gas analyzer

DR= 1:100

T_1=150°C

T_2=Tamb

T_{EC}=300°C

Engine operating conditions

Gasoline ***G-PFI*** **Gasoline** ***G-DI*** **Ethanol** ***E-DI***

DF ratio

[Gasoline]/([Ethanol]+[Gasoline]) *100

DF80
DF50

Urban driving conditions

3000 rpm WOT
4000 rpm WOT
5000 rpm WOT

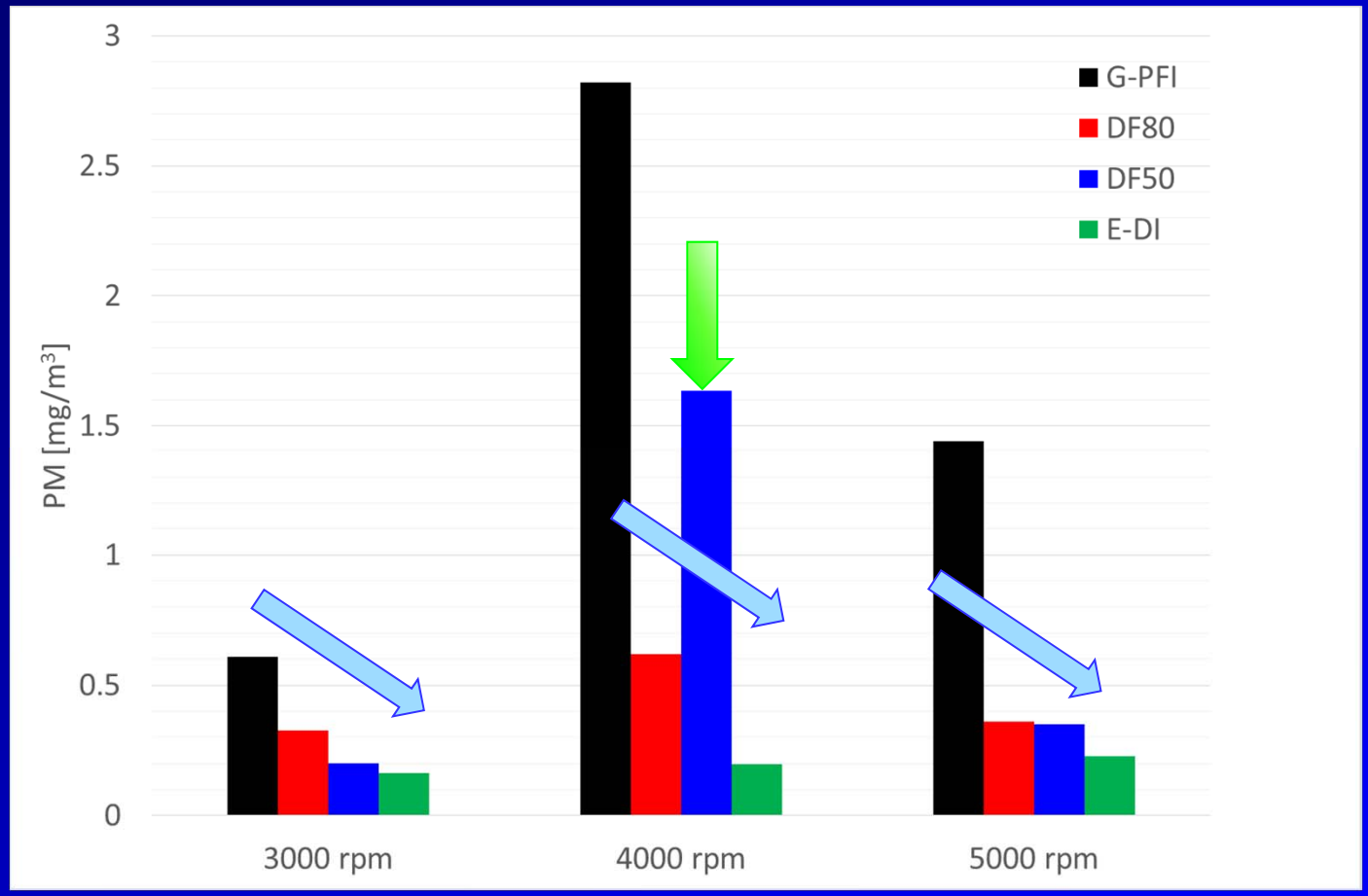
→

λ 1.0

SOS 22 BTDC @ 3000 rpm
24 BTDC @ 4000 rpm
24 BTDC @ 5000 rpm

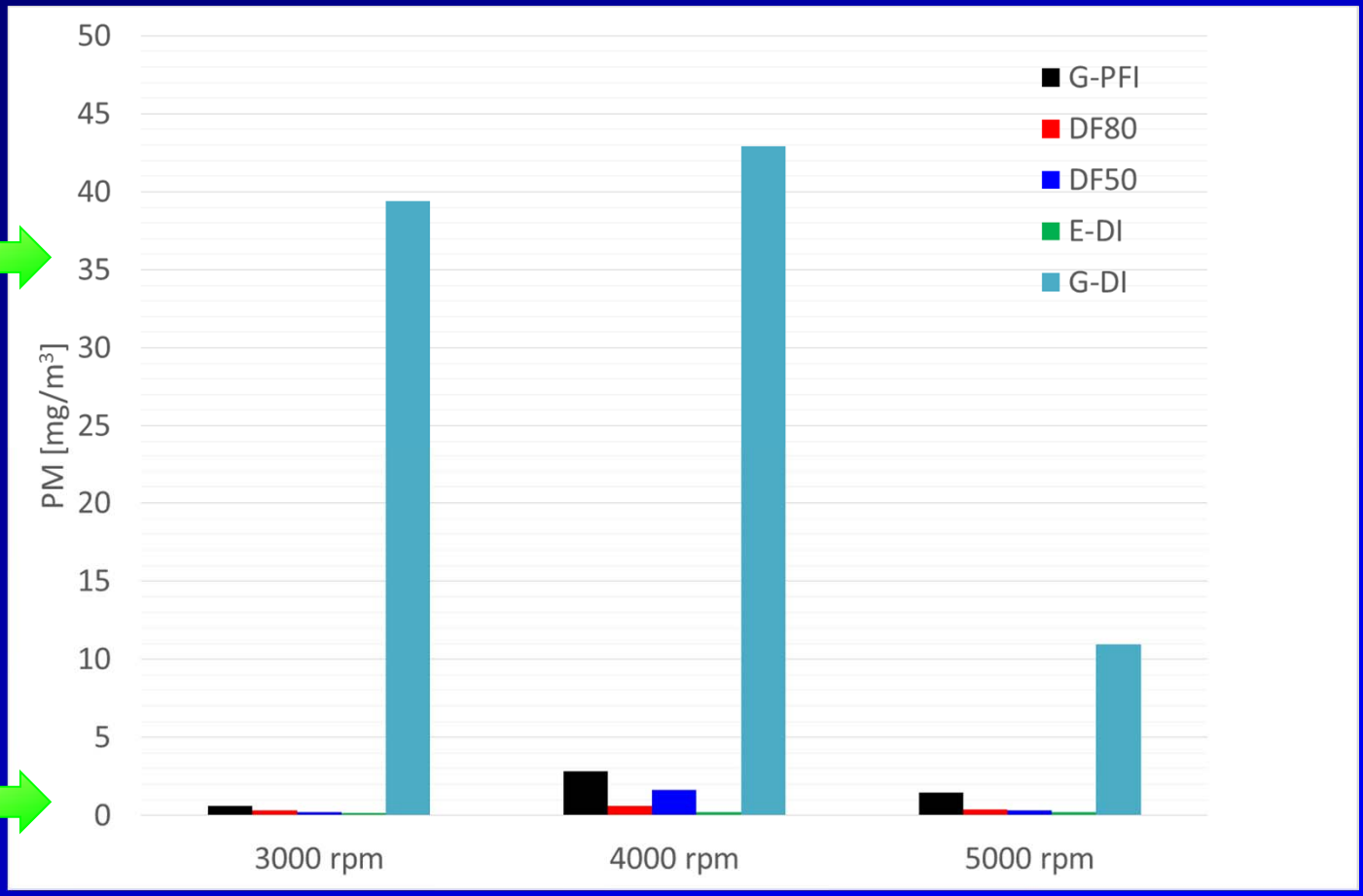
SOI 230 PFI
315 DI

Particle Mass Concentration



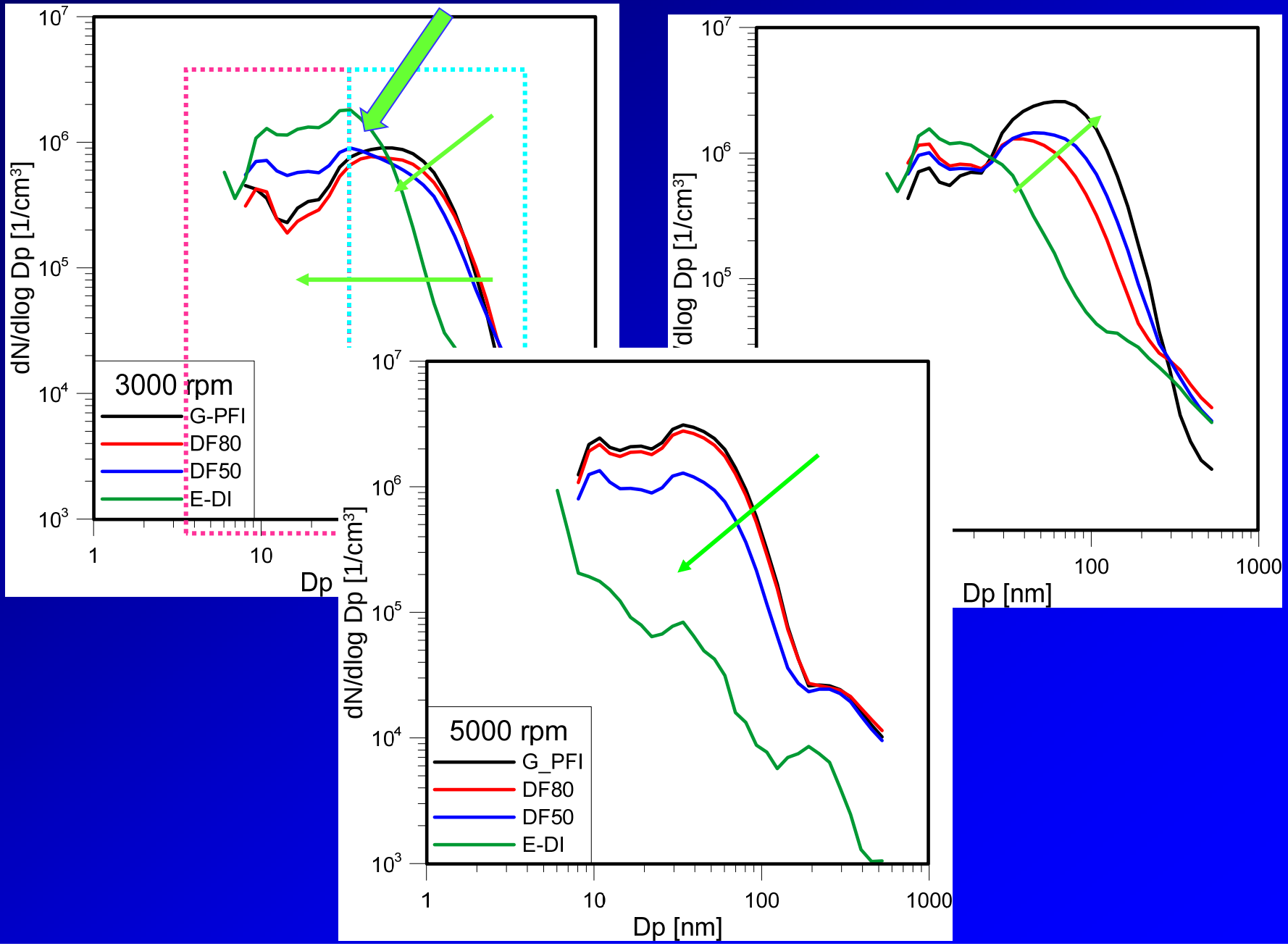
DF80: 80% gasoline (PFI) 20% ethanol (DI)
DF50: 50% gasoline (PFI) 50% ethanol (DI)

Particle Mass Concentration



DF80: 80% gasoline (PFI) 20% ethanol (DI)
DF50: 50% gasoline (PFI) 50% ethanol (DI)

Particle Size Distribution



Particle Size Distribution

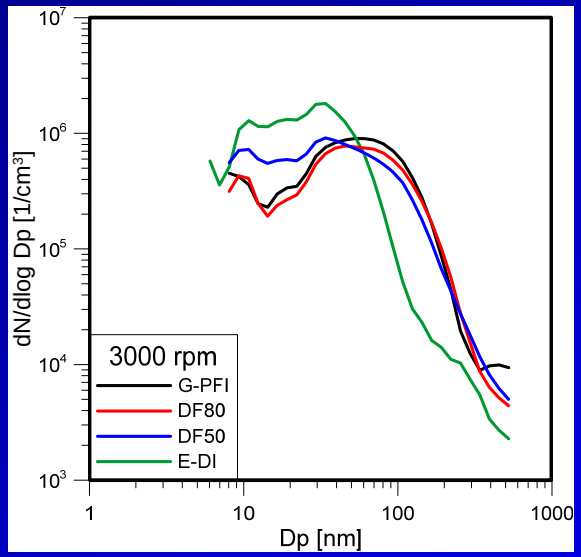
Oxygen content

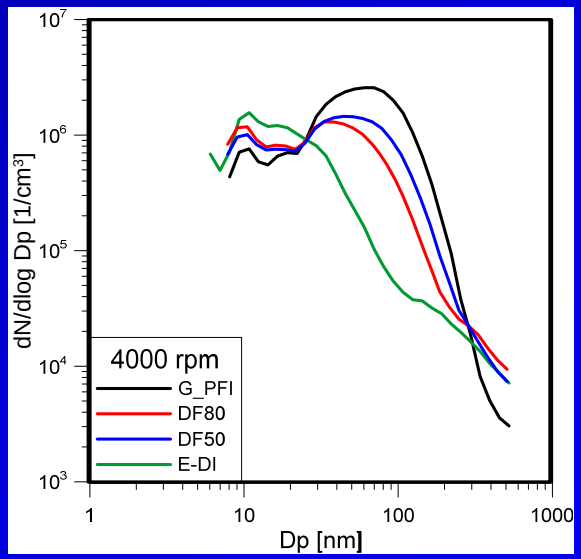
Reduced soot precursor formation
Enhanced soot oxidation

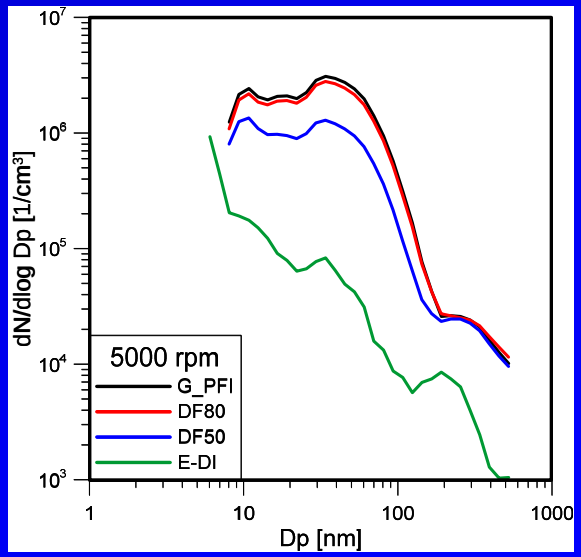
Volatility properties

Evaporation conditions

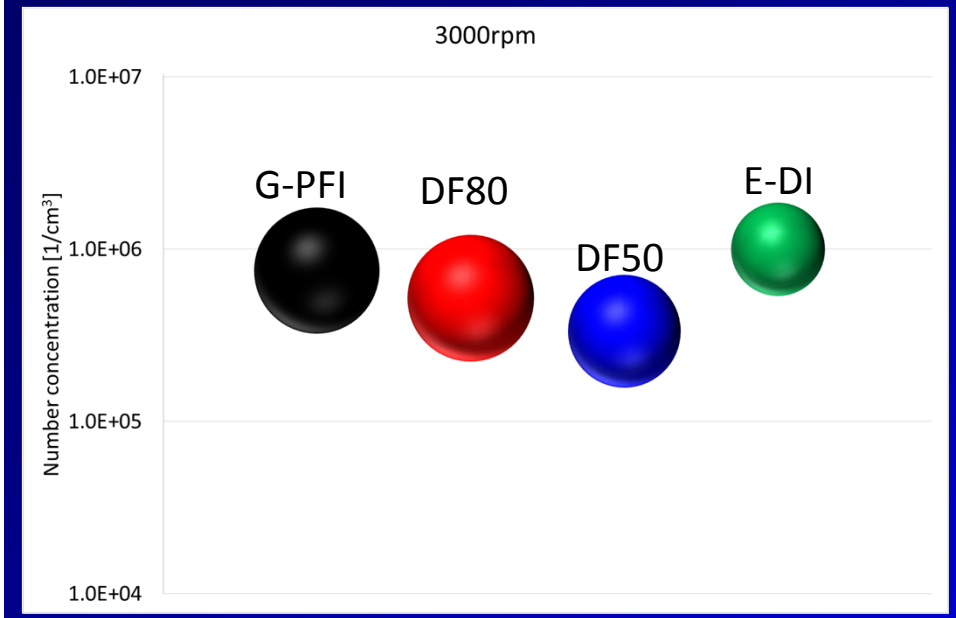
Enhanced evaporation of lighter compounds of gasoline: residual fuel will mainly contain heavier and highly sooting hydrocarbons

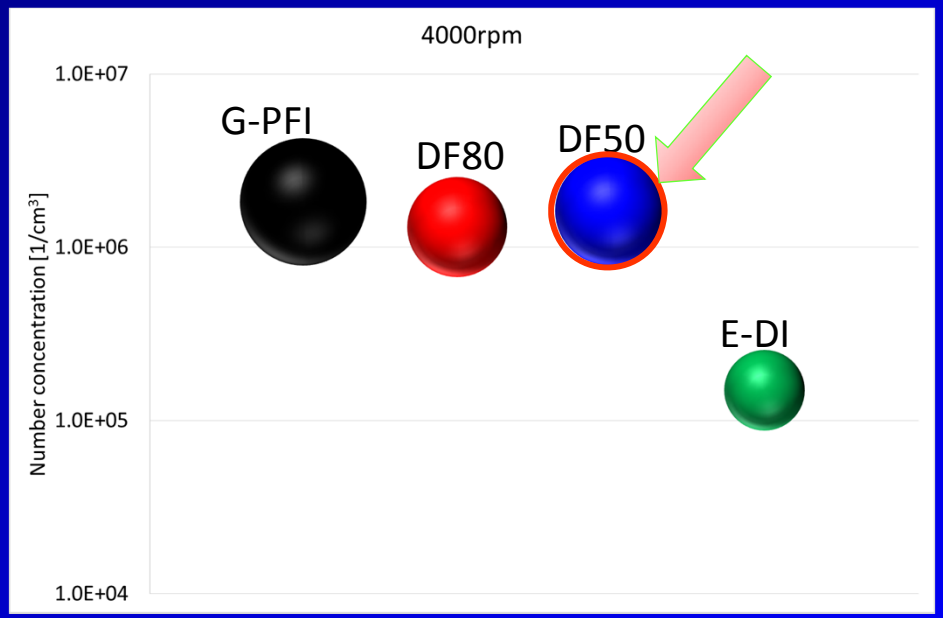






Particle Size and Number



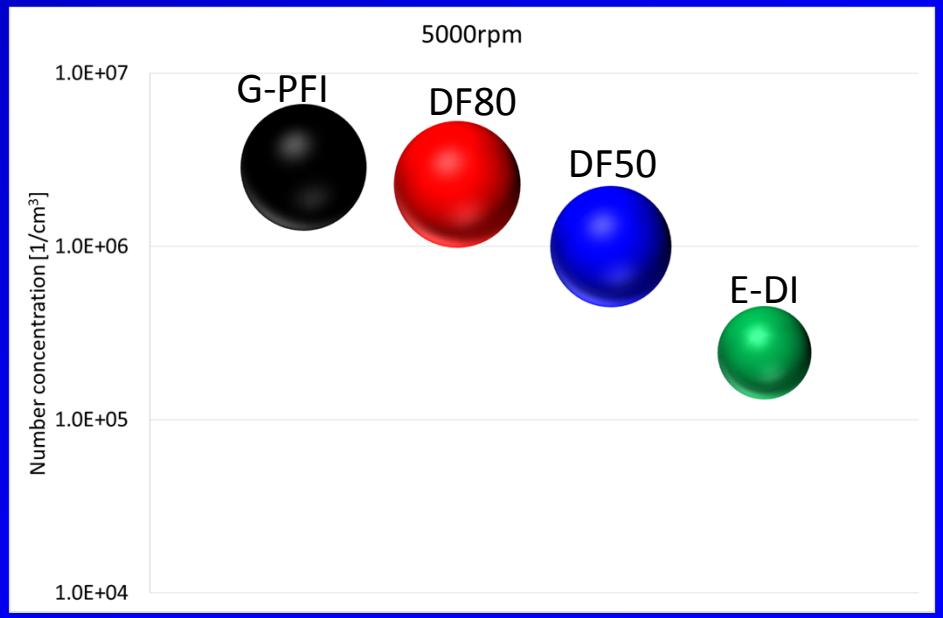


Particle Number

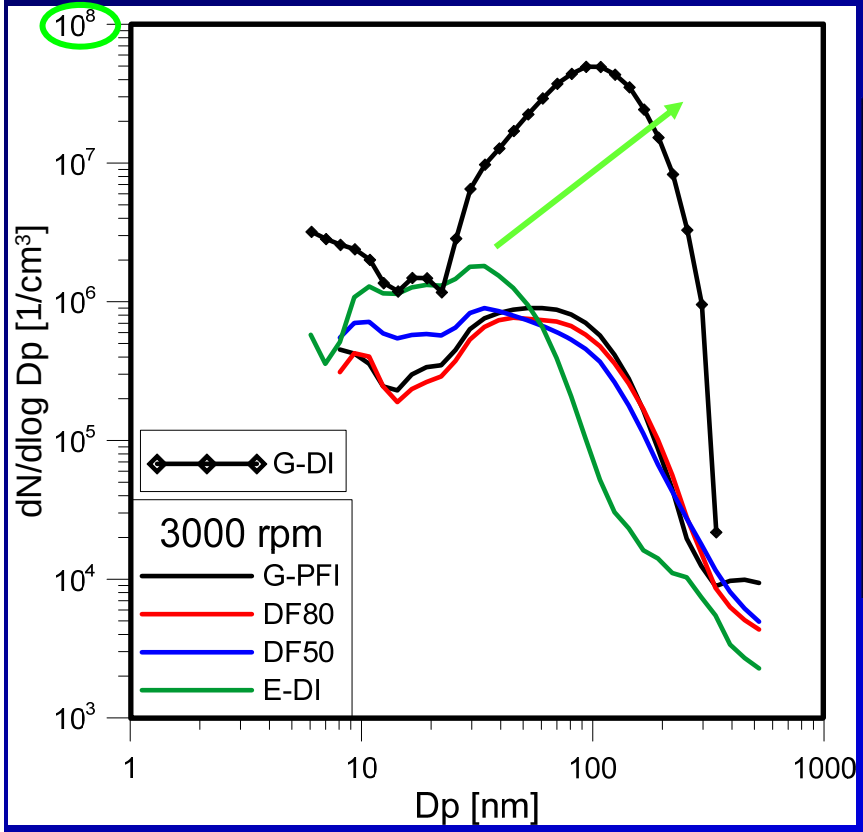
$$N_i = \frac{dN_i / d\log D_p}{16}$$

Mean Particle Diameter

$$D_m = \frac{\sum_{i=1}^{n} D_{p,i} \cdot N_i}{\sum_{i=1}^{n} N_i}$$

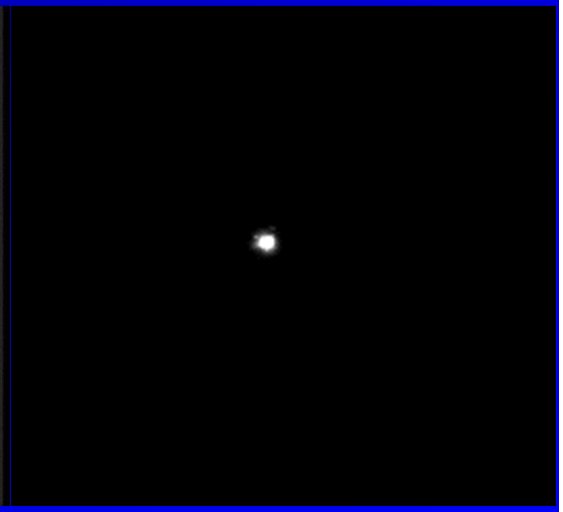


Particle Emissions: DF vs GDI

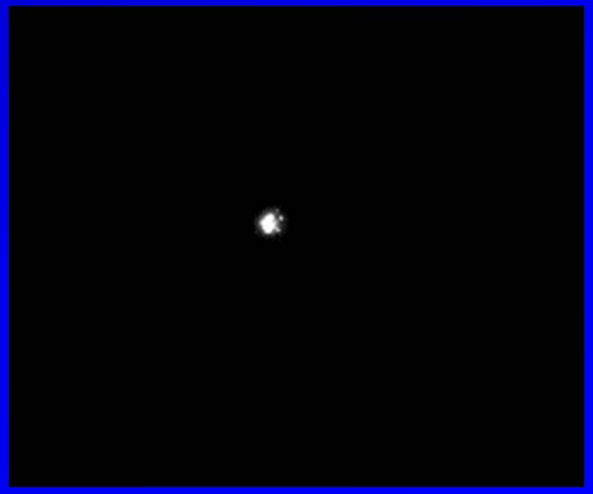


G-PFI

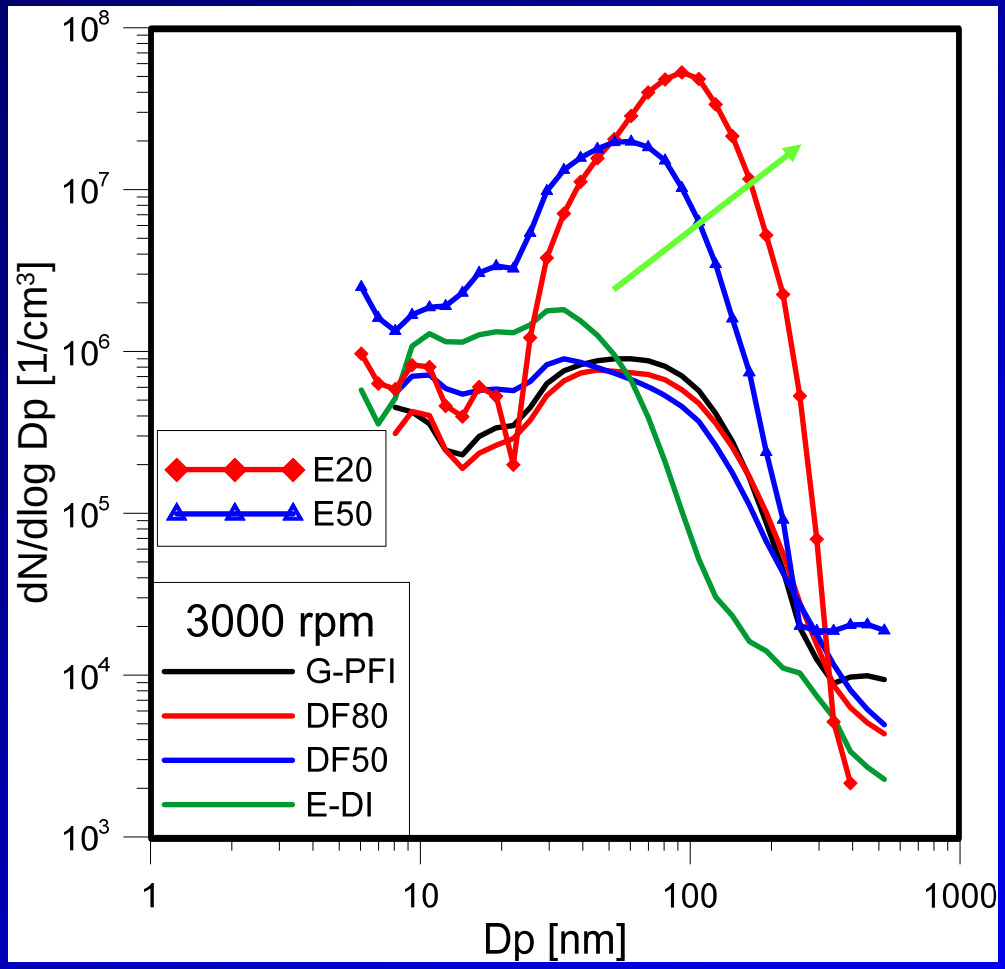
G-DI



DF



Particle Emissions: DF vs Blends



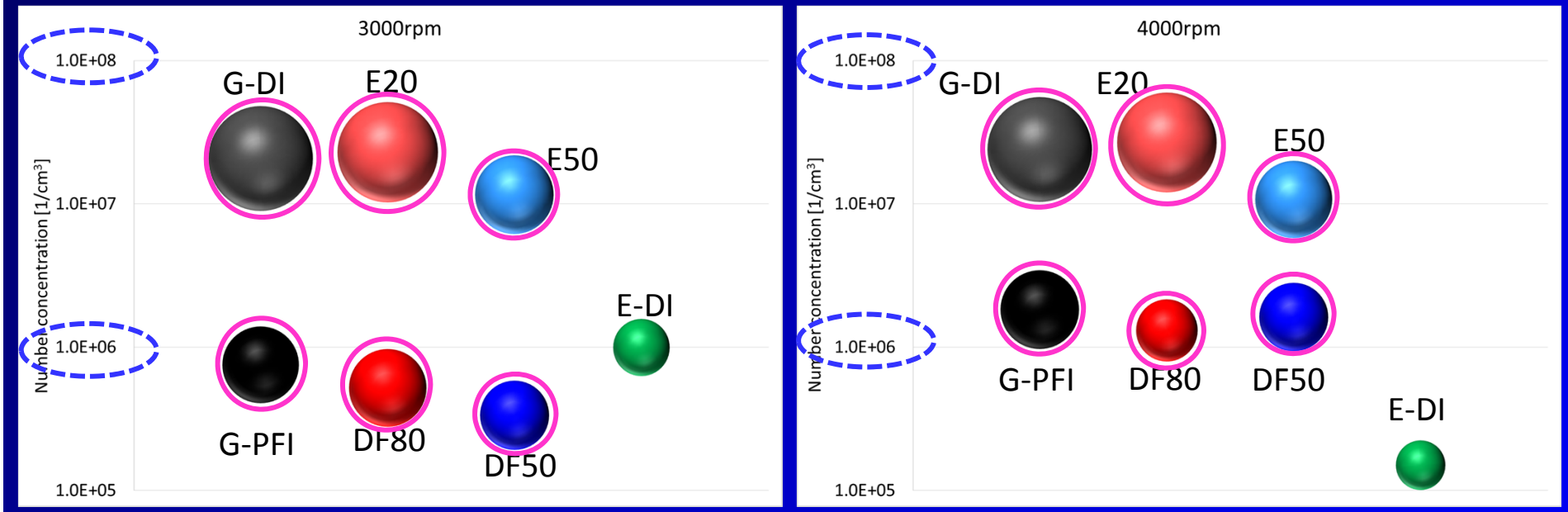
DF80
80% gasoline (PFI)
20% ethanol (DI)

E20
80% gasoline (DI)
20% ethanol (DI)

DF50
50% gasoline (PFI)
50% ethanol (DI)

E50
50% gasoline (DI)
50% ethanol (DI)

Exhaust Particle Size and Number



DF80:

80% gasoline (PFI) 20% ethanol (DI)

E20:

80% gasoline (DI) 20% ethanol (DI)

DF50:

50% gasoline (PFI) 50% ethanol (DI)

E50:

50% gasoline (DI) 50% ethanol (DI)

Conclusions 1 / 2

The effects of the **ethanol/gasoline dual fueling** on the particle emissions in a small **SI** engine was investigated.

Engine worked at **3000 rpm, 4000 rpm** and **5000 rpm full load** representative of urban driving conditions.

Engine was fueled with pure ethanol and gasoline and different dual fuel ratio of ethanol in gasoline (***DF80-DF50***).

A smoke meter were used for particle concentration measurement.

A Engine Exhaust Particle Sizer (**EEPS**) was used for counting and sizing of the particles in the size range **5.6-560 nm.**

Conclusions 2 / 2

Particle mass decreases with ethanol content except for ***DF50 @ 4000 rpm;***
Particle number & size decreases with ethanol content except for ***DF50 @ 4000 rpm***.

The particle emissions is strongly affected by:

- ***Fuel:***
  - *oxygen content*: sooting reduction tendency;
  - *evaporation rate*: selective and enhanced evaporation of ethanol and lighter compounds of gasoline: favorable conditions for the formation of particles from the sooting compounds of gasoline;
- ***Engine operating point:***
  - *In-cylinder temperature:* affects evaporation conditions.

Thank you for the attention

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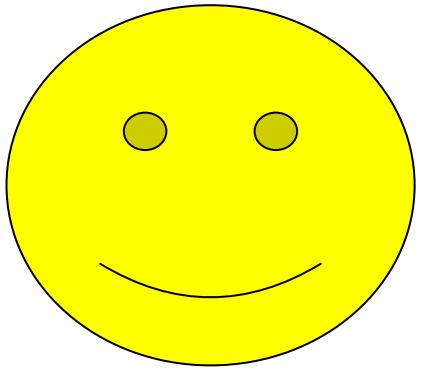

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