Joint FINAL EVENT

UPGRADE

dieper

25 September 2019 Graz Austria

# "Particle emissions from GDI combustion system"

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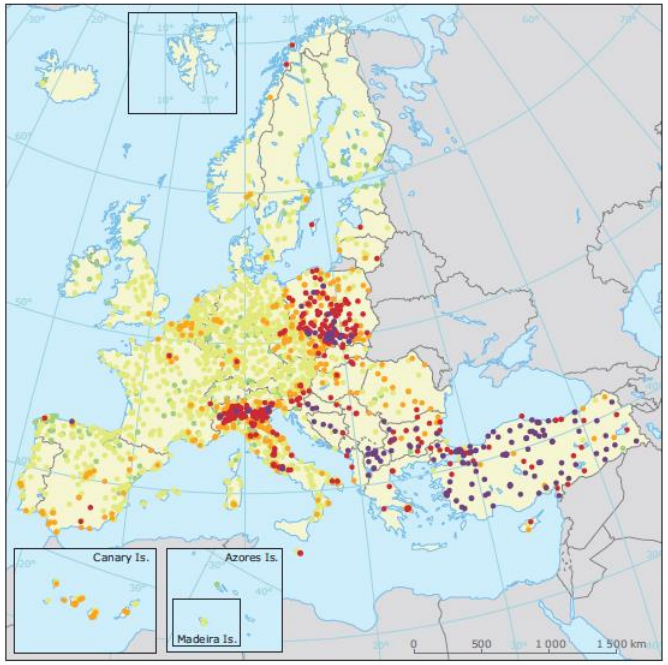
# Common concerns...

**Map 3.1** Concentrations of $PM_{10}$, 2016 — daily limit value




## Pollution levels remain high in the EU

**Map 6.1** Concentrations of $NO_2$, 2016

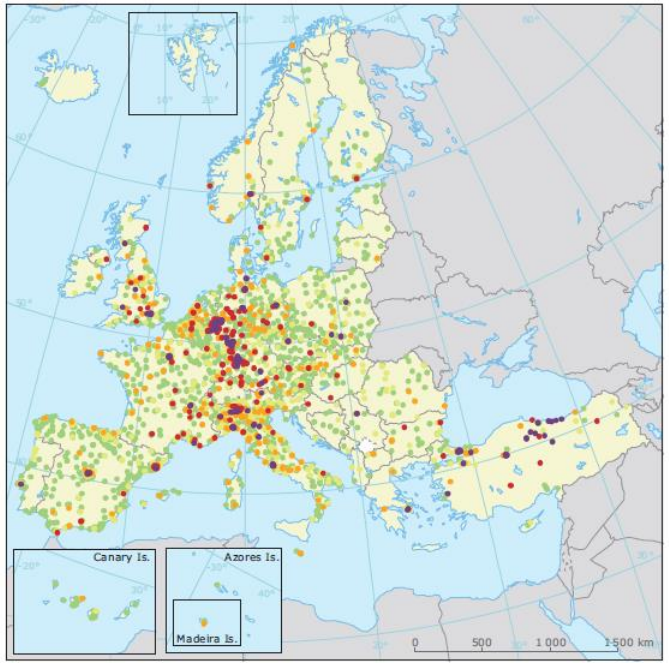
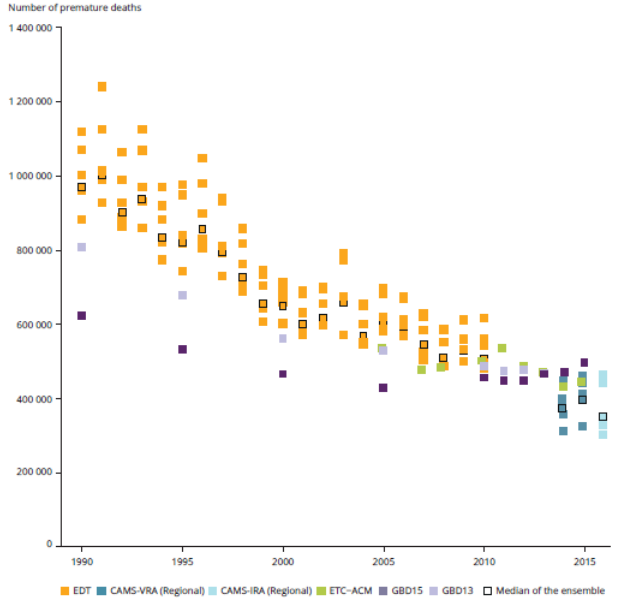


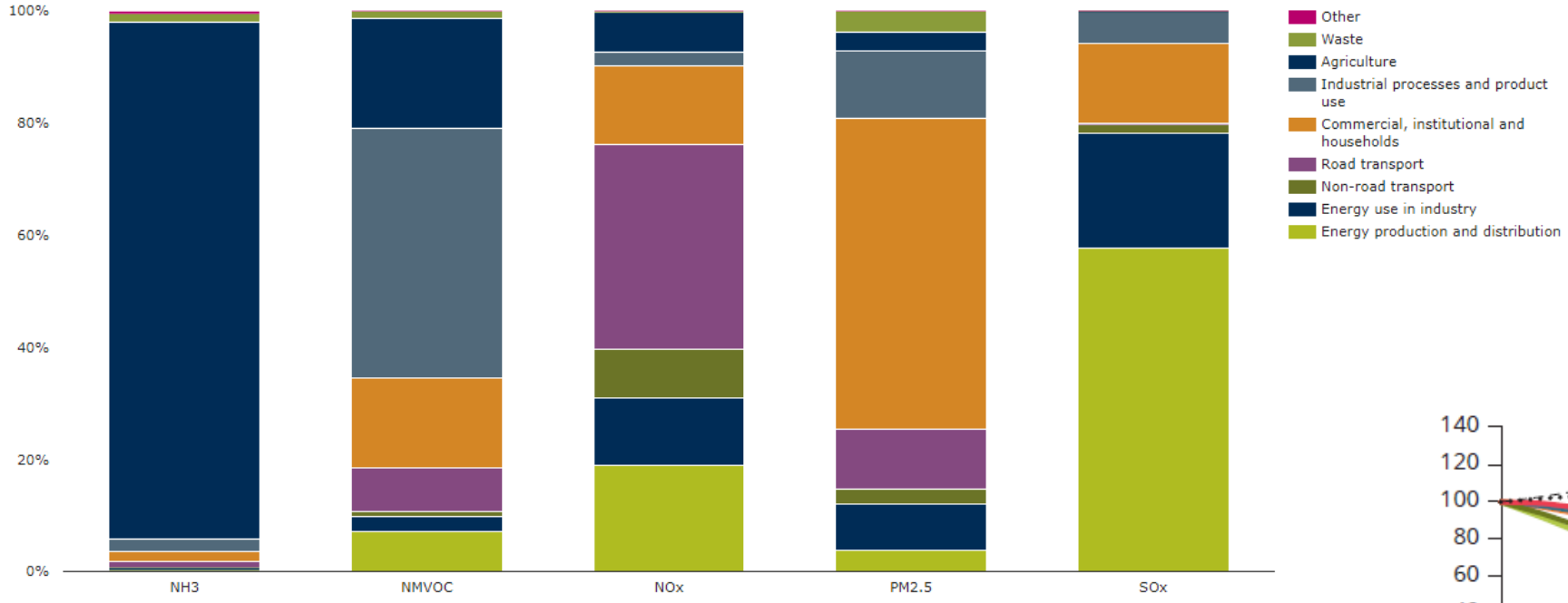

**Figure 10.1** Premature deaths due to exposure to $PM_{2.5}$ (all-cause (natural) mortality) in Europe over the period 1990-2016 for various data sets of $PM_{2.5}$ concentration



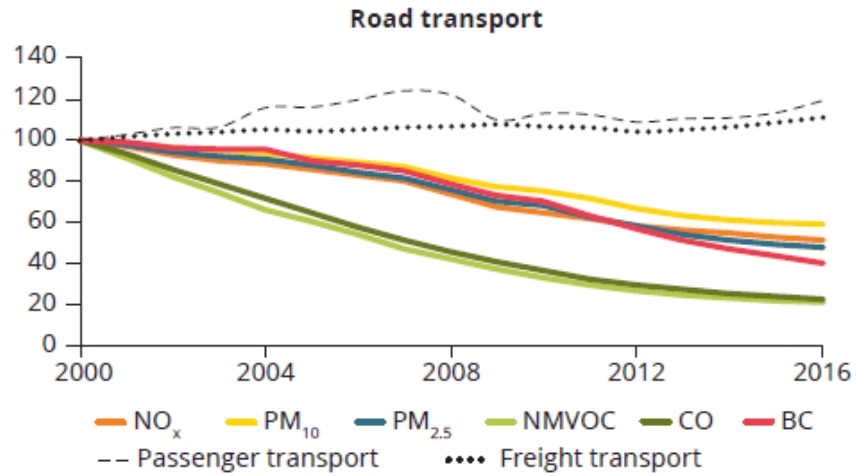

*Source: EEA Air Quality report 2018*

# …but OEMs technology improvements have an impact

**Emissions of the main air pollutants by sector group in the EEA - 33**




*Source: EEA 2019 report*




**For road transport, emissions of key pollutants (e.g. NOx) have decreased significantly, although transported passenger and freight volume has increased and stayed relatively constant.**

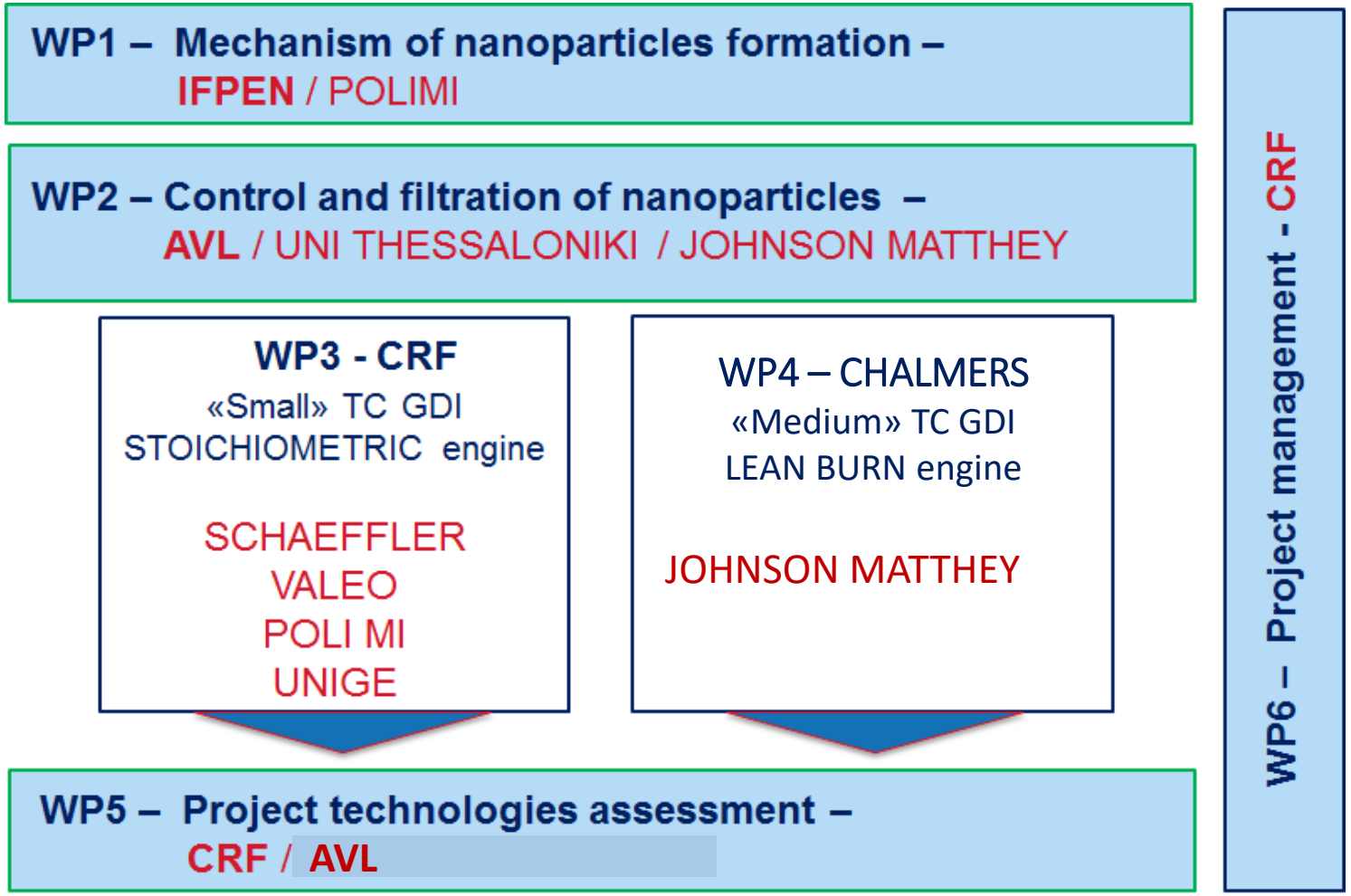
# UPGRADE objectives

***Demonstrate the future role of the conventional ICE aiming to contribute to the environmental challenges with particular regard to noxious and GHG emissions***

**HOW**

- Development of **two advanced high efficient and clean engine platforms**
- **S**tudy and development of **new simulation models** to predict nanoparticles and pollutant formation inside the combustion chamber
- Analysis and development of the after-treatment technologies focusing on **new GPF technologies** targeting PN filtration down to 10 nm diameter
- Realization of **one full demonstrator vehicle** to assess the overall targets on the WLTC and the compliancy with Euro 6 RDE standards

# Project structure

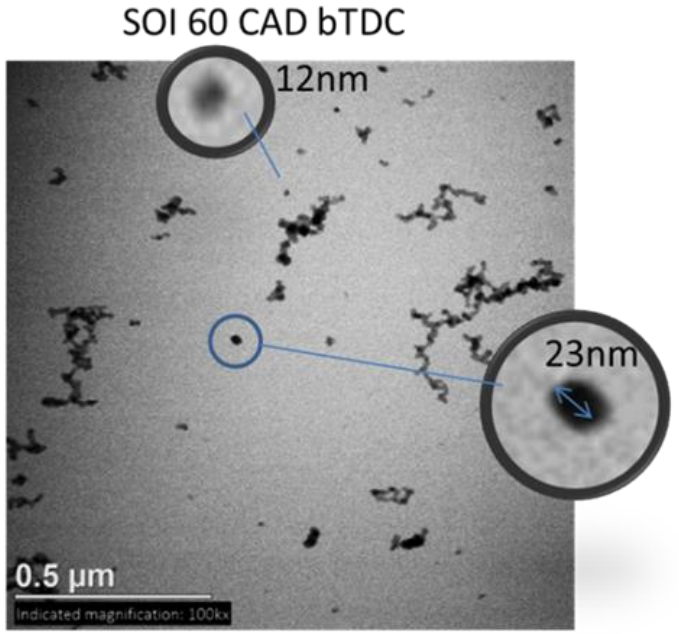


# WP1 – Study of the Mechanisms of Nano Particles formation

A test campaign on an Optical single cylinder engine was performed

- Large number of parametric variations (injection strategies, mixture dilution, in-cylinder aerodynamics, fuel oxygen content…)
- Identification pool fires remain main mechanism for soot formation
  - strong link with liquid film / wall impingement
- Quantitative exhaust measurements and in-cylinder soot particle sampling

➔**input for CFD model development and validation**

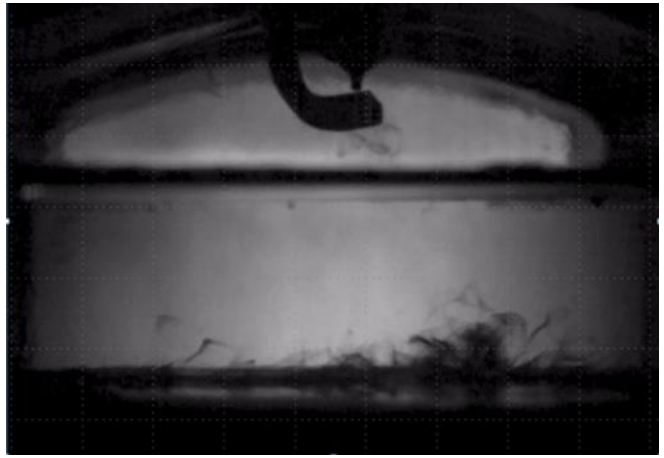


# WP1 – Soot modeling applied to GDI engines simulations

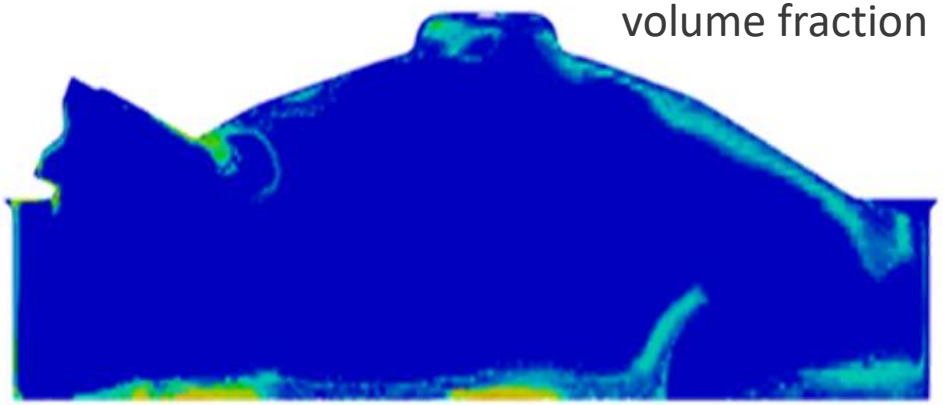
New soot models developed and implemented into commercial CFD codes :

- Advanced fuel film modeling
- Improved chemistry in 3D CFD simulations
- Soot model predicting size distributions

→ **Improve CFD engineers ability to design and develop GDI engines**

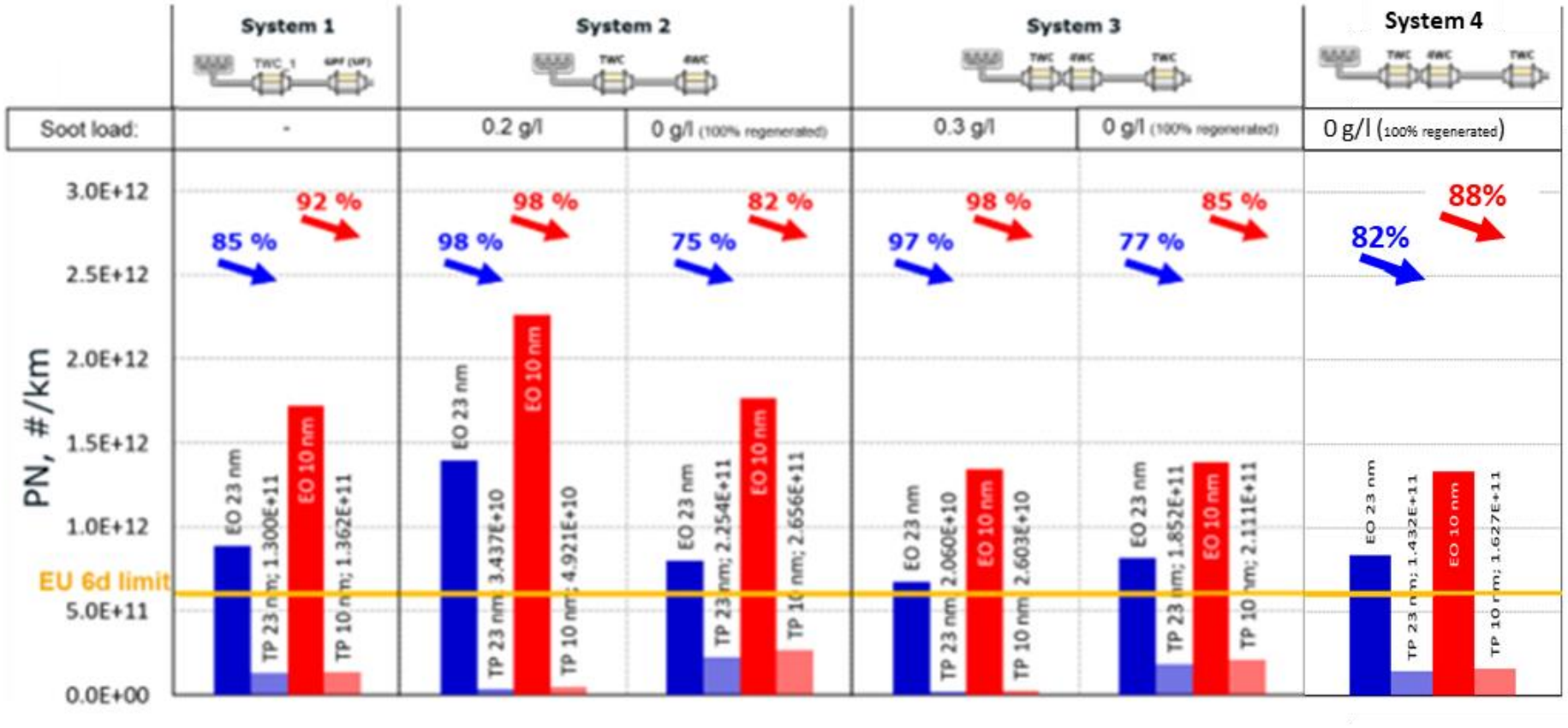


Calculated soot volume fraction

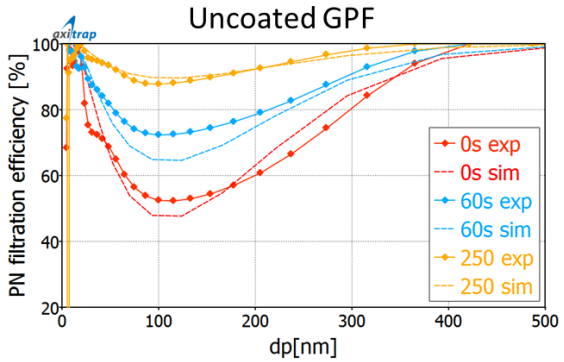


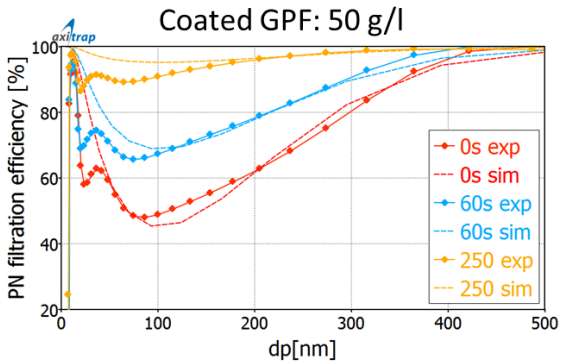
# WP2: Nanoparticle Filtration – Experimental Testing

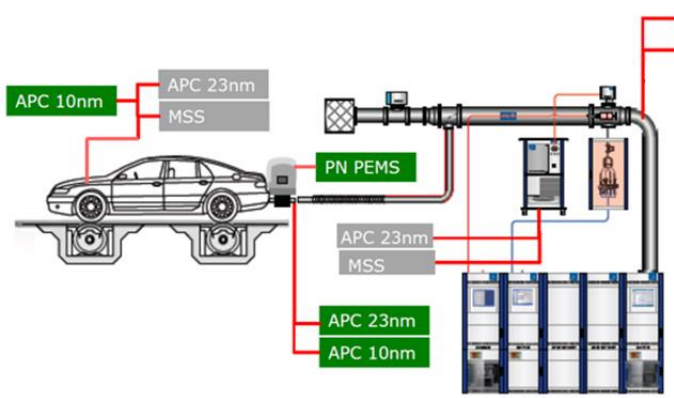
RDE moderate driving style, 23°C

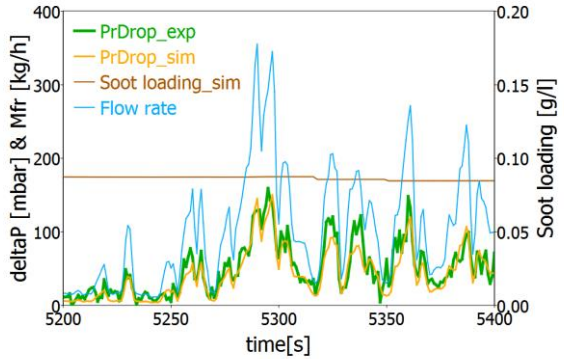


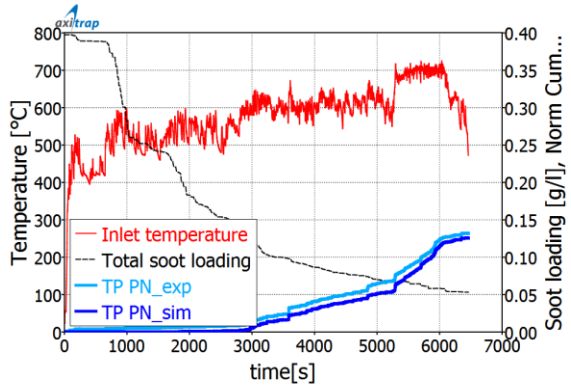
# WP2 Nanoparticle Filtration – Simulation

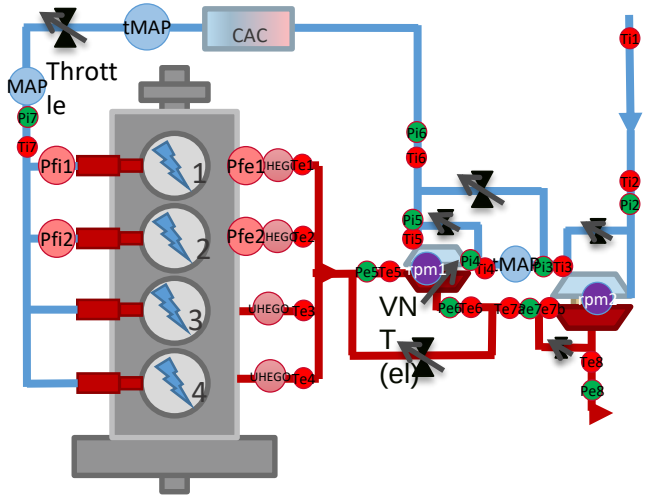



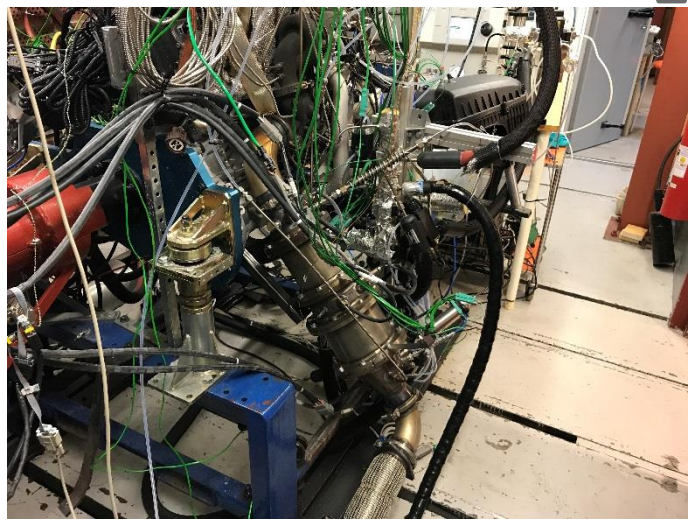




Predictive pressure drop & size-resolved FE models for GPF filters of different washcoat loading under both steady state and transient conditions.

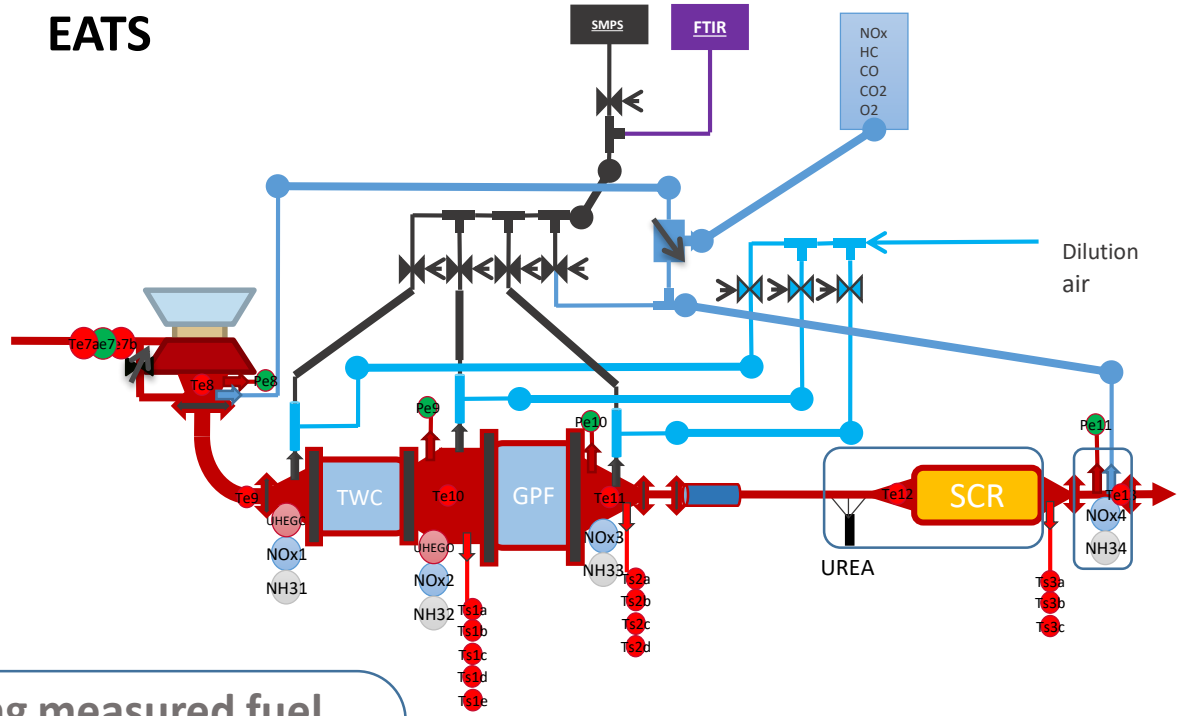
# WP4 – TC GDI lean burn engine

## Lean Burn Engine



## EATS




Vehicle simulations using measured fuel consumption maps show up to 7 % reduction in fuel consumption for the WLTP-cycle, in line with the goal of the WP

# WP3: TC GDI stoichiometric engine

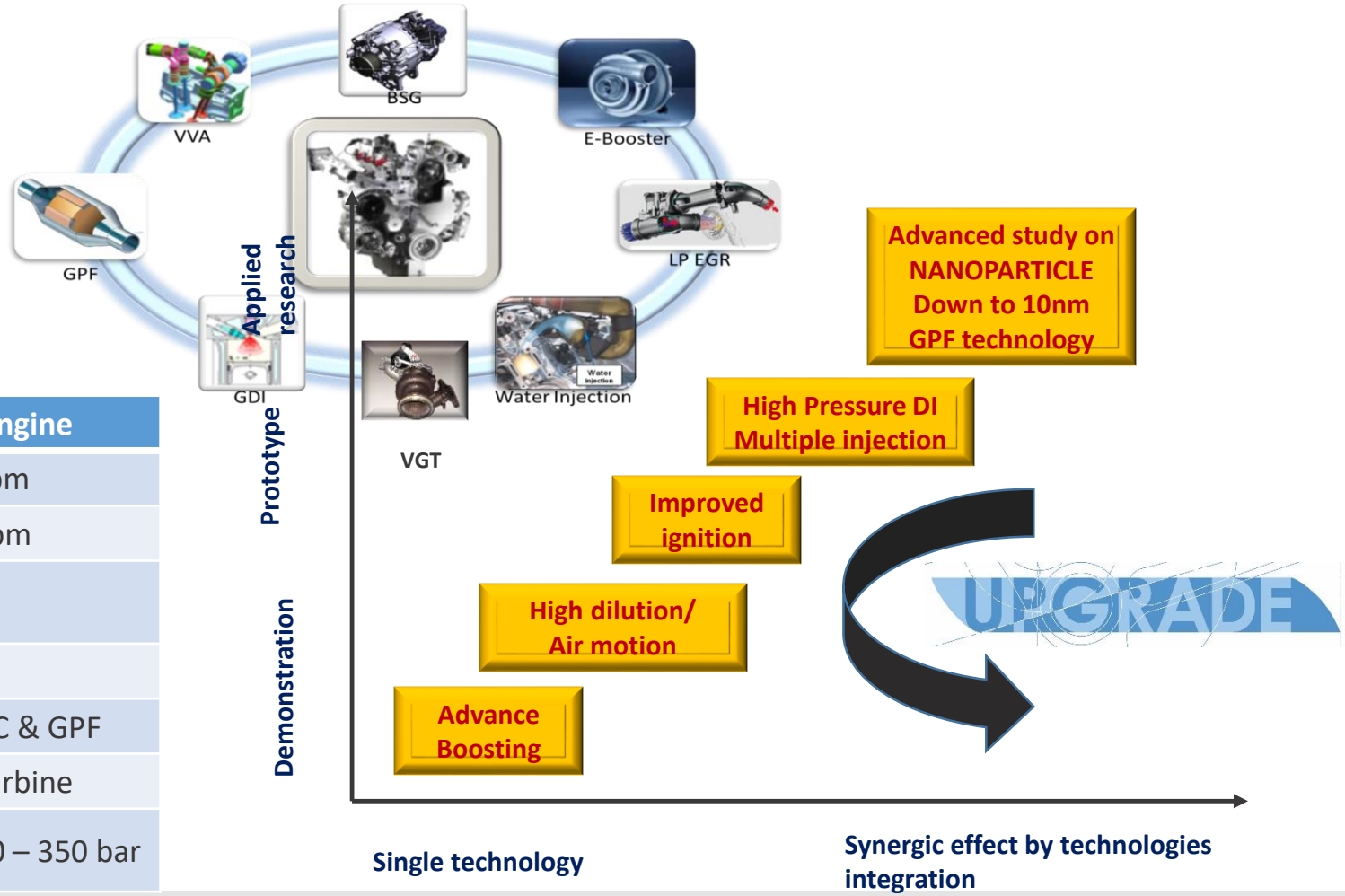
## Main objectives

- New small downsized turbocharged Spark Ignited engine
- New technologies and control strategies on the intake air path
- Advanced concept for air boosting/Low Pressure EGR cooled loop
- CFD model to study/optimize the combustion process → PN emission control and reduction
- Low voltage BSG system
- New Gasoline Particulate Filter technology
- Prototype engine realization and calibration
- Demo vehicle set up, calibration and final assessment

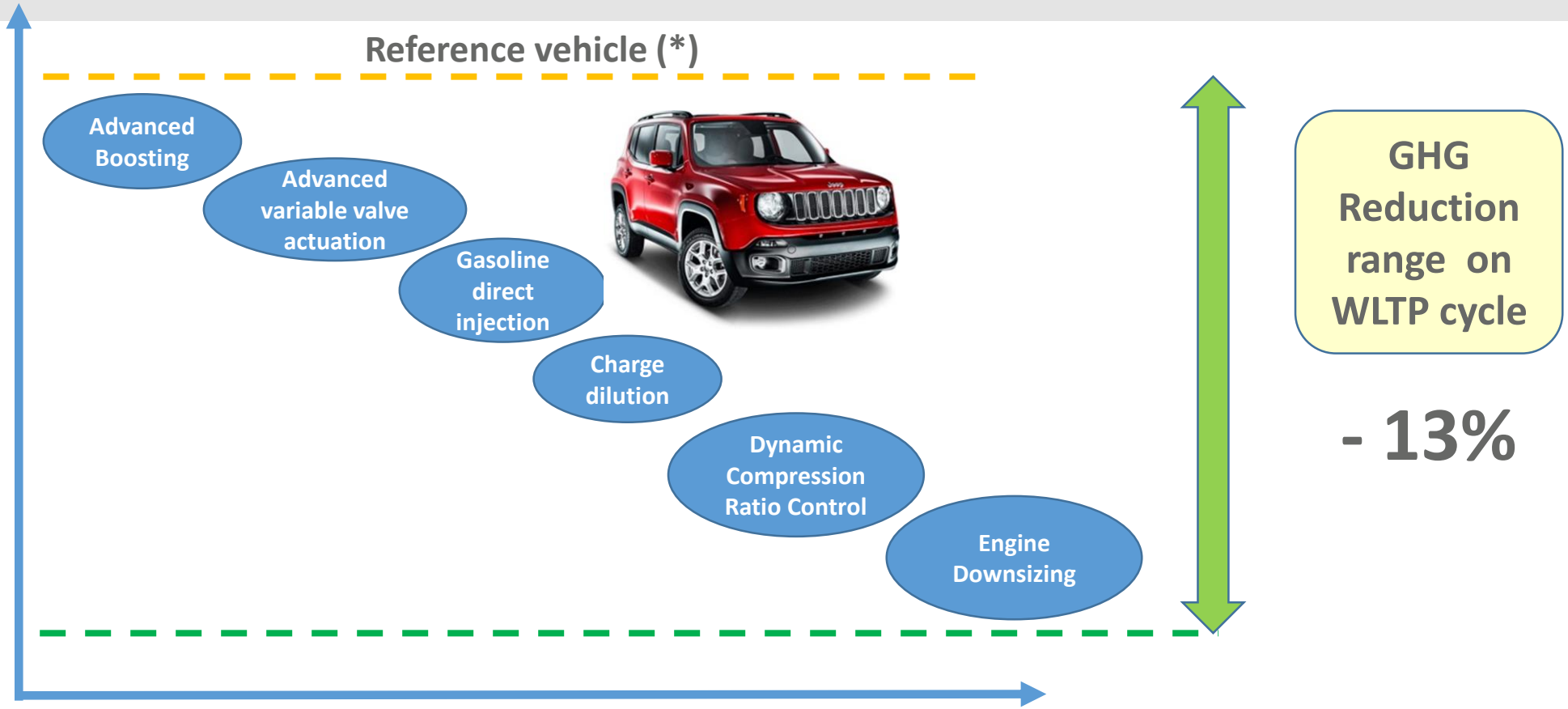
- CALL TARGET: reduction of WLTP $CO_2$ emissions of **15% for gasoline**, with respect to the best equivalent size and torque engines on the market in 2015 and real driving emissions at least below upcoming Euro 6 RDE limits (with particle number emissions measured with a 10 nm threshold).

# UPGRADE technologies positioning

| Engine | 1.0L 3cyl UPGRADE Engine |
|---|---|
| Power | 120 CV @ 5500 rpm |
| Torque | 190 Nm @ 1750 rpm |
| Geometrical CR | 13 |
| Intake cam | Extreme Late |
| EGR System | EGR Sample before TWC & GPF |
| Turbocharger | Variable Geometry Turbine |
| FIS | High pressure FIS Range 50 – 350 bar |



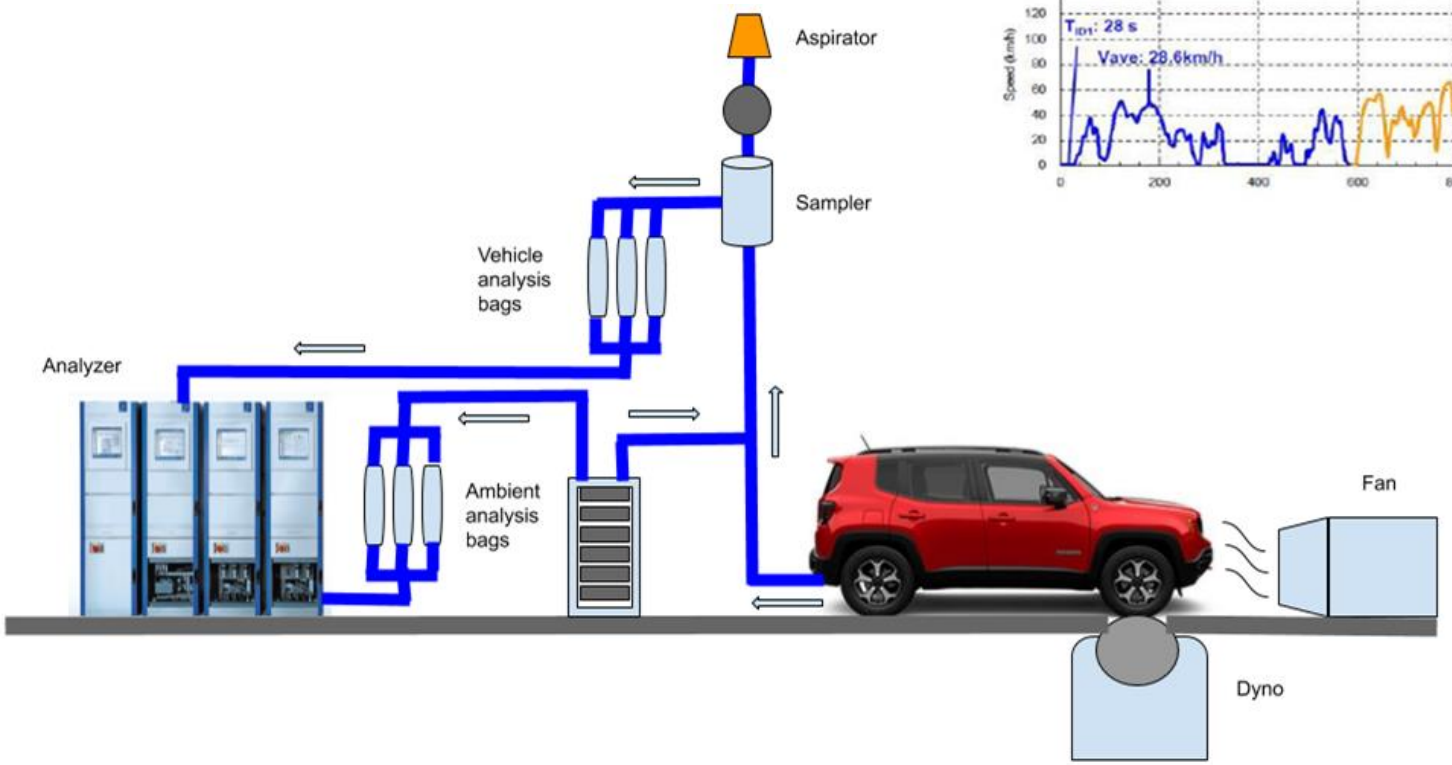
# $CO_2$ emission reduction walk



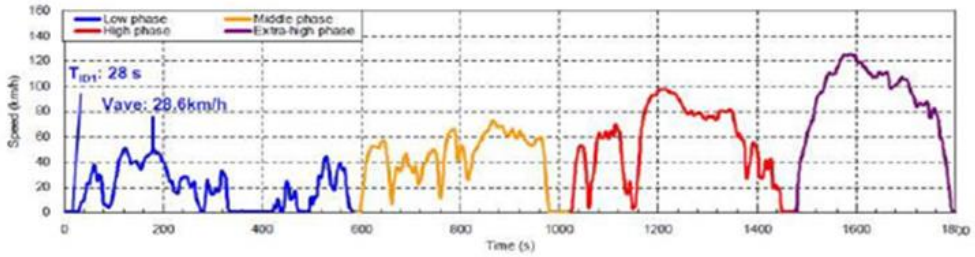

**Further 1,5% $CO_2$ reduction on WLTC can be achieved with the contribution of 12V Belt Starter Generator (BSG) combined with a dedicated FEAD (Front End Accessories Drive**

*(*) Jeep Renegade 1.4 TC MultiAir® 140 CV*

# Vehicle tested at JRC facilities

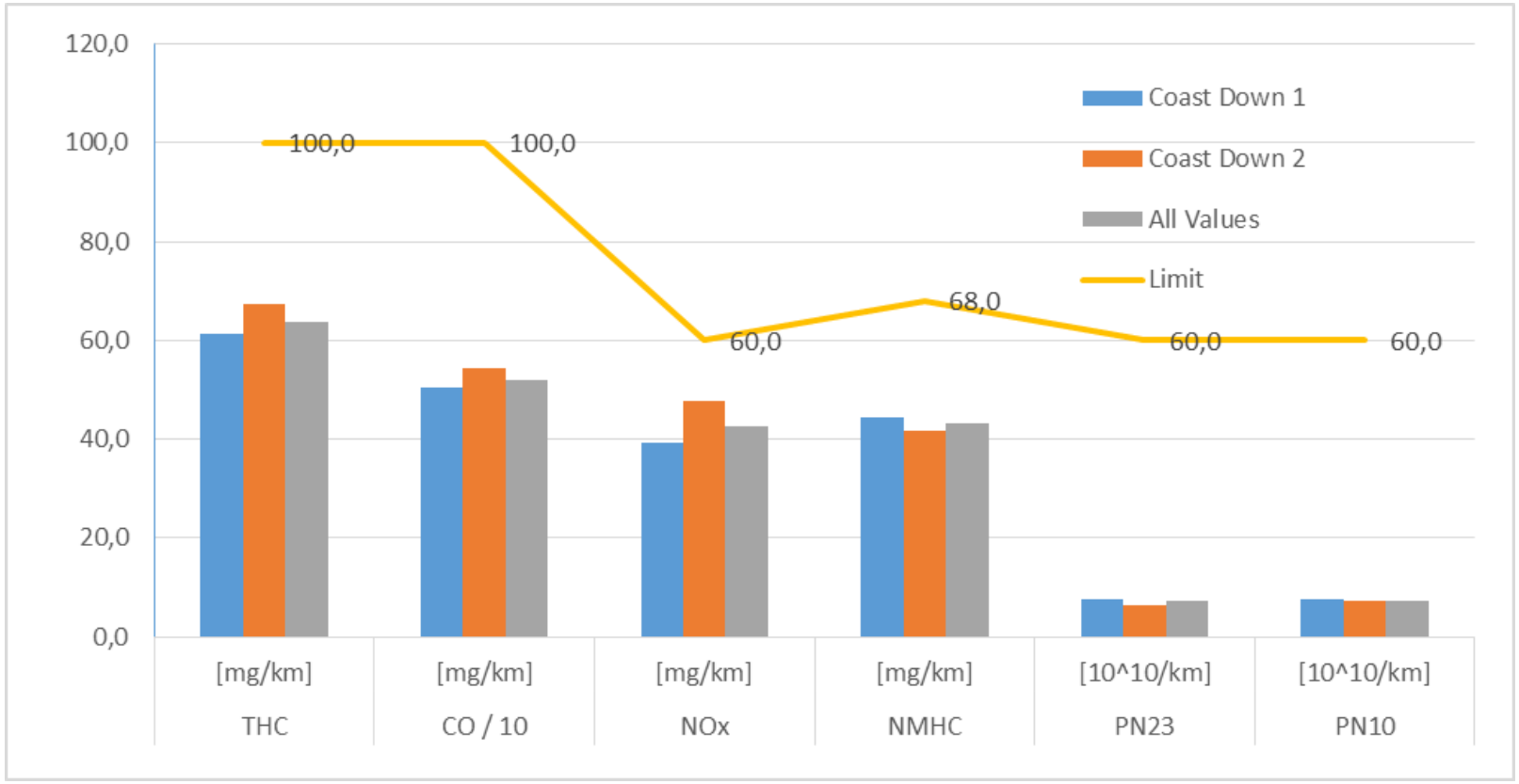



**WLTC speed profile**



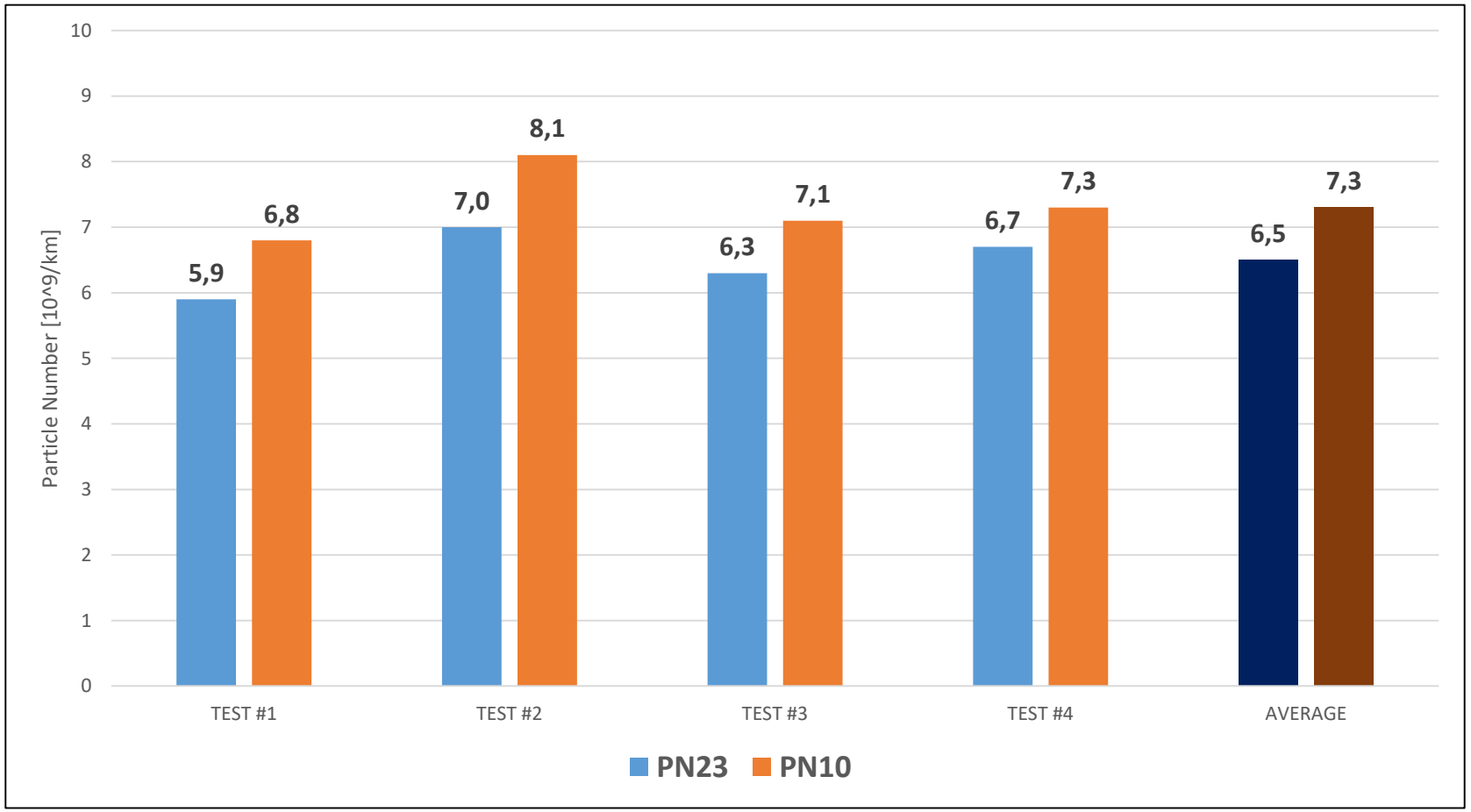

4 Phases
1800 sec long
46 km/h average velocity
125 km/h max velocity

# WLTC test results




**All the pollutants emission are under the EURO 6D limits**

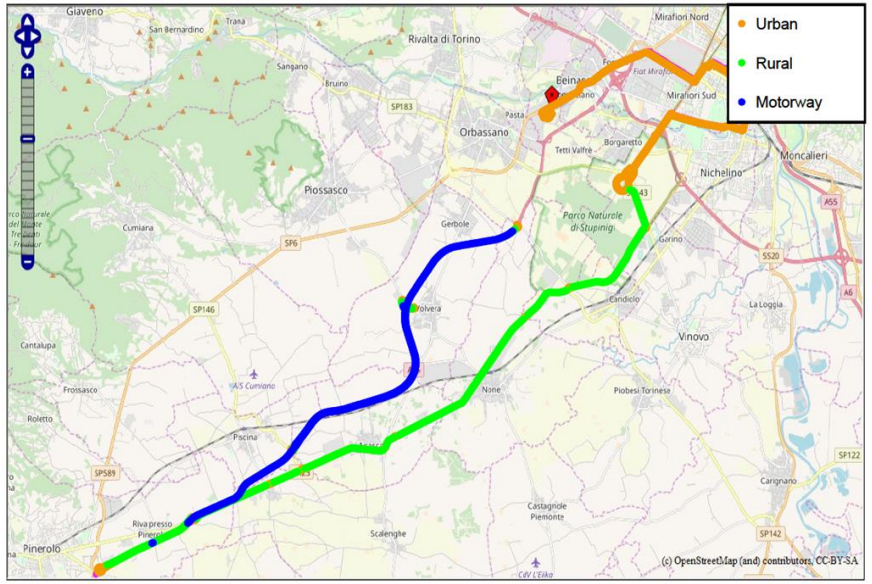
# PN measurement on WLTC @ JRC

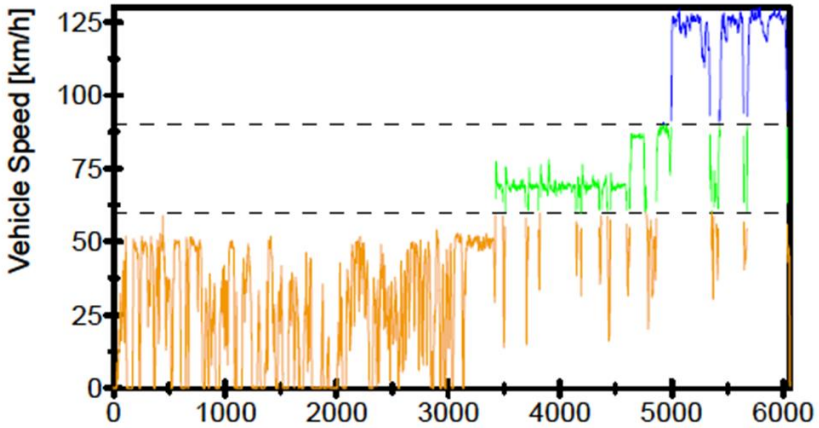



**Current limit value for PN 23 = $6*10^{11}$**

**Two orders of magnitude below the limit**

# RDE tests with PEMS




Trip Composition

| | Unit | Urban | Rural | Motorway | Total Trip |
|---|---|---|---|---|---|
| Duration | min:s | 62:22 | 23:13 | 15:28 | 101:03 |
| Distance | km | 29.0 | 27.9 | 31.8 | 88.7 |
| Distance Share | % | 32.7 | 31.5 | 35.8 | --- |
| Average Speed | km/h | 27.9 | 72.2 | 123.2 | 52.6 |

# PEMS emission results

Several RDE tests with the UPGRADE vehicle have been carried out

Average emission PEMS results

| Pollutant | Unit | Final Emission | NTE Pollutant |
|---|---|---|---|
| CO | mg/km | 413,9 | - |
| $NO_x$ | mg/km | 24,2 | 85,8 |
| NO | mg/km | 15,3 | - |
| $NO_2$ | mg/km | 8,9 | - |
| PN | #/km | 4,7E+09 | 9E+11 |

**All the NTE pollutant requirements are satisfied**

# Conclusions

- **The UPGRADE project demonstrated the potential of gasoline engine/vehicles as key pillar for current and future passenger cars by means of innovative solutions**
- **New technologies and simulation models are available to support further efforts to reduce PN emissions even below 10 nm**
- **Hybrid solutions will be able to further contribute to reduce the environmental impact of ICE in road transportation**

# Thank you

## Any questions?

These projects have received funding from the European Union's Horizon2020 Programme for research, technological development and demonstration under Grant Agreement No. 724036 (UPGRADE) and No. 723976 (dieper)