HORIZON 2020

Call: H2020-GV-2016-2017

Technologies for low emission light duty powertrains

Measuring automotive exhaust particles down to 10 nm

Zissis Samaras, on behalf of the "DownToTen" Project consortium

Co-authors and partners

- LAT/AUTh, Thessaloniki, Greece
  - Leonidas Ntziachristos
  - Tasos Kontses
  - Zisimos Toumasatos
- TU Graz, Austria
  - Alex bergmann
  - Stefan Hausberger
  - Markus Bainschab
  - Lukas Landl
- AVL, Austria
  - Thanasis Mamakos
- Tampere University Finland
  - Jorma Keskinen
  - Panu Karjalainen
- TU Munich, Germany
  - Christoph Haisch
- Ricardo, UK
  - Jon Andersson

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The DTT structure

- Key aspects of DTT structure
- Evolution of particle emission study

Results and analysis

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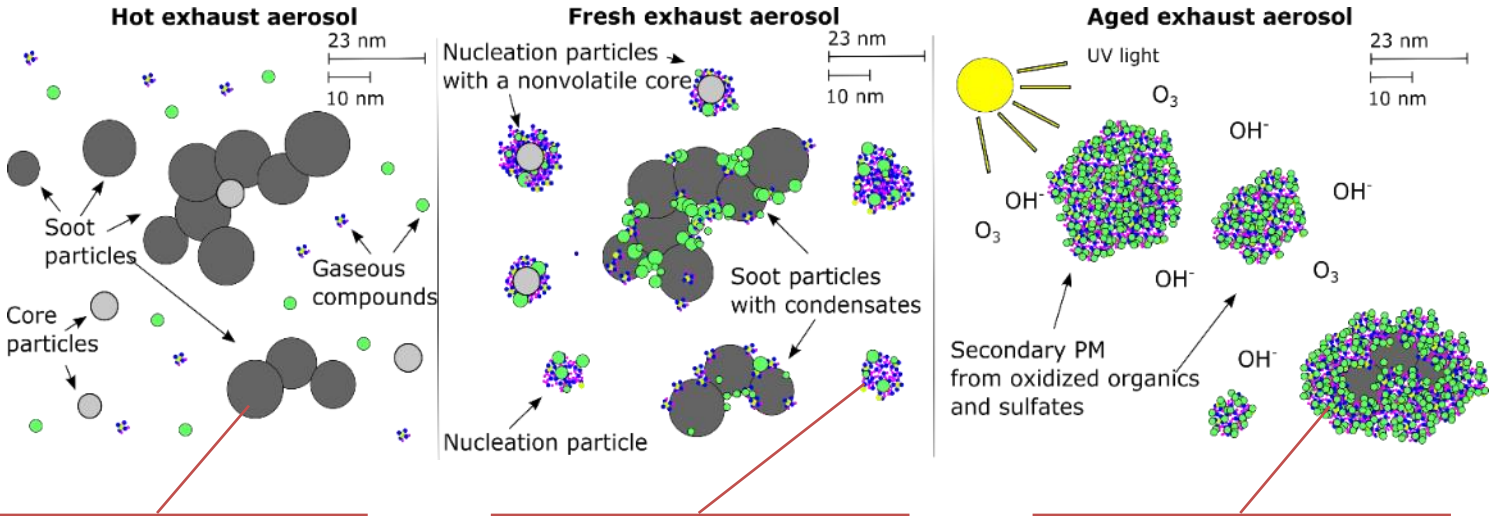
Current regulation & exhaust aerosol

Tailpipe (ms to s) … Roadside (s to min) … Urban Environment (h)



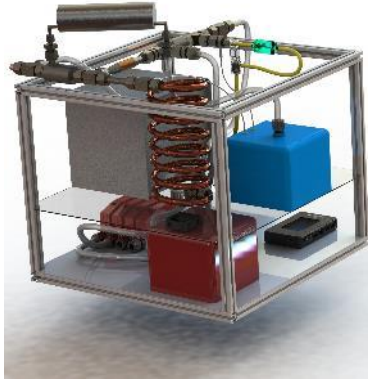
Controlled under current regulation (non-volatile >23nm)

Dominant at roadside (volatile incl. <23nm)

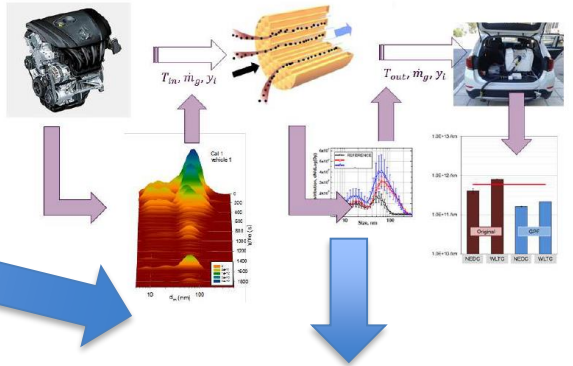
Aged particles (what urban populations are mostly exposed to)

Objectives & Targets

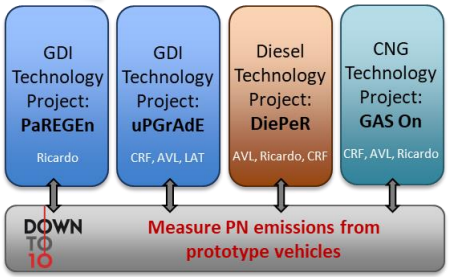
1. Develop instrumentation and sampling setup to measure exhaust particles as small as 10nm



2. Develop models and new measurement techniques to understand particle chemistry and transformation in the sampling system

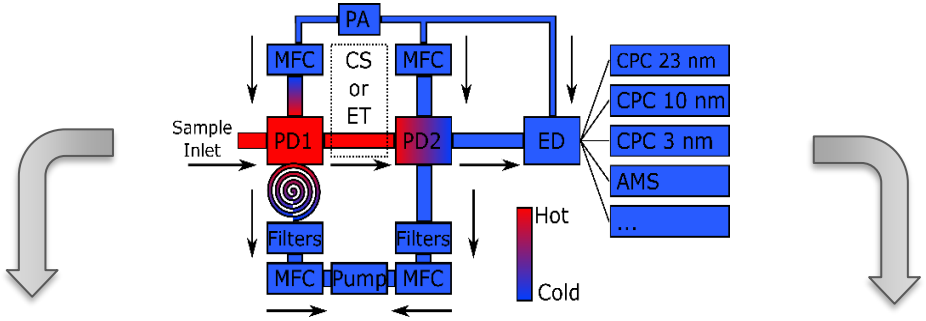


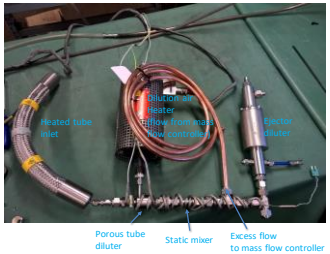
3. Use new setup to measure latest vehicle technologies
(collaboration with parallel H2020 projects)

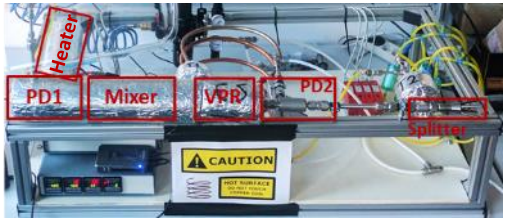


4. Synthesize results to provide policy recommendations incl. metrology (WP5)

Three generations of sampling system







1st GEN: Testing principles prototype

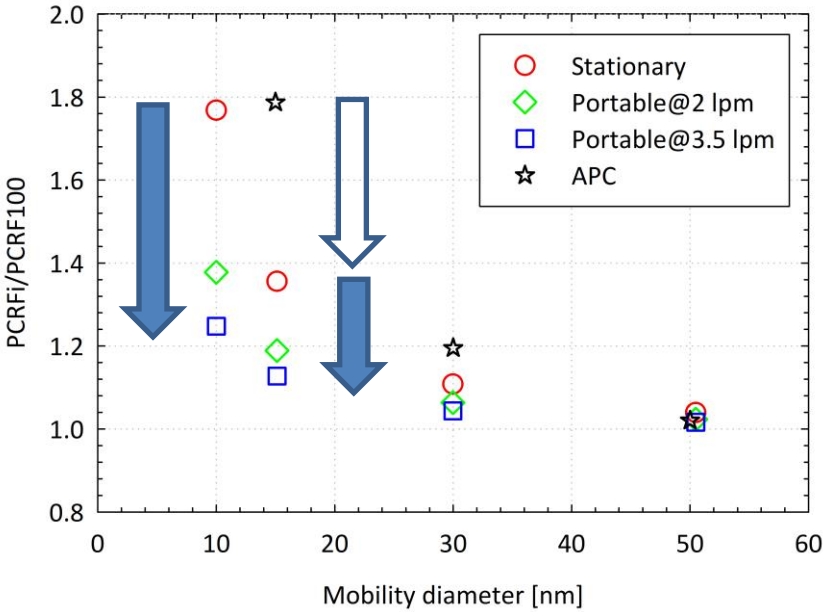
2nd GEN: Lab implementation prototype

3rd GEN: PEPS implementation

- **Low loss sampling system**
- **Flexibility in sampling**
  - Opt. 1: Current PMP
  - Opt. 2: Enhanced VPR including CS
  - Opt. 3: No VPR
- **Capacity for PN-PEMS (PEPS)**
  - Counterflow diluter
  - Low energy consumption (~100 W)
  - Battery-powered
- **Possibility for different PN modes**
  - Hot exhaust (non-volatile primary)
  - Fresh aerosol (delayed primary)
  - Aged exhaust (secondary)

Particle Penetration 3rd generation

- Stationary system shows less particle size dependence than commercially available APC
- Portable system brings further improvement



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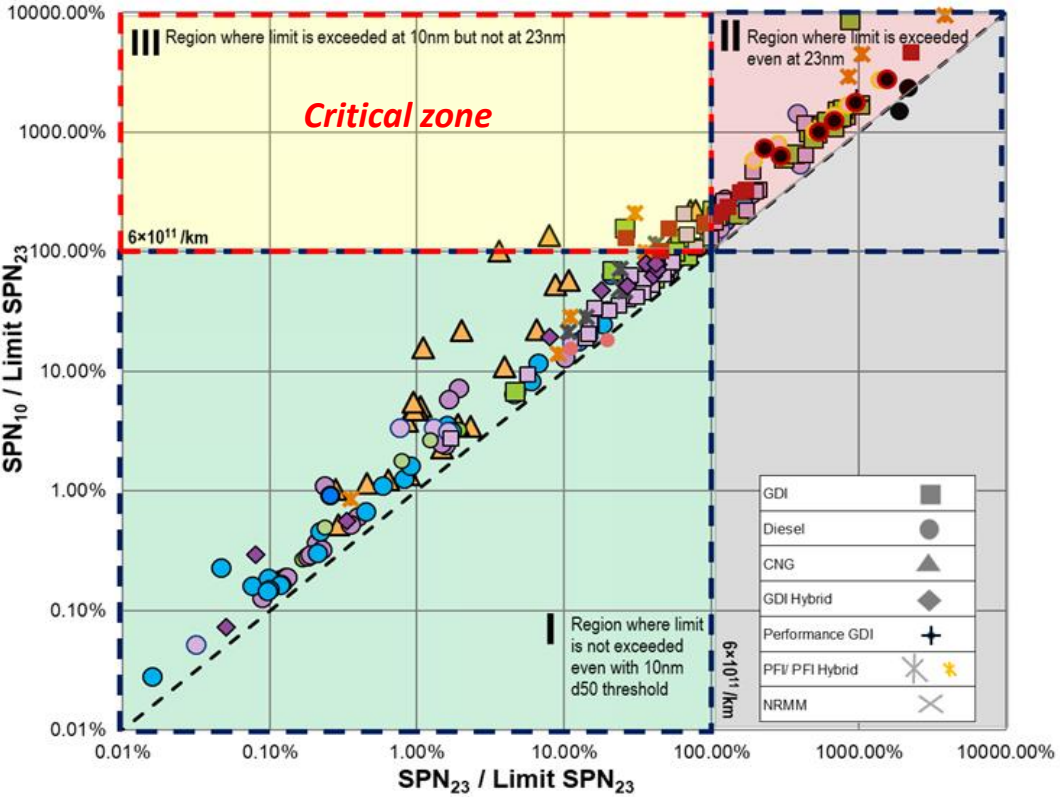
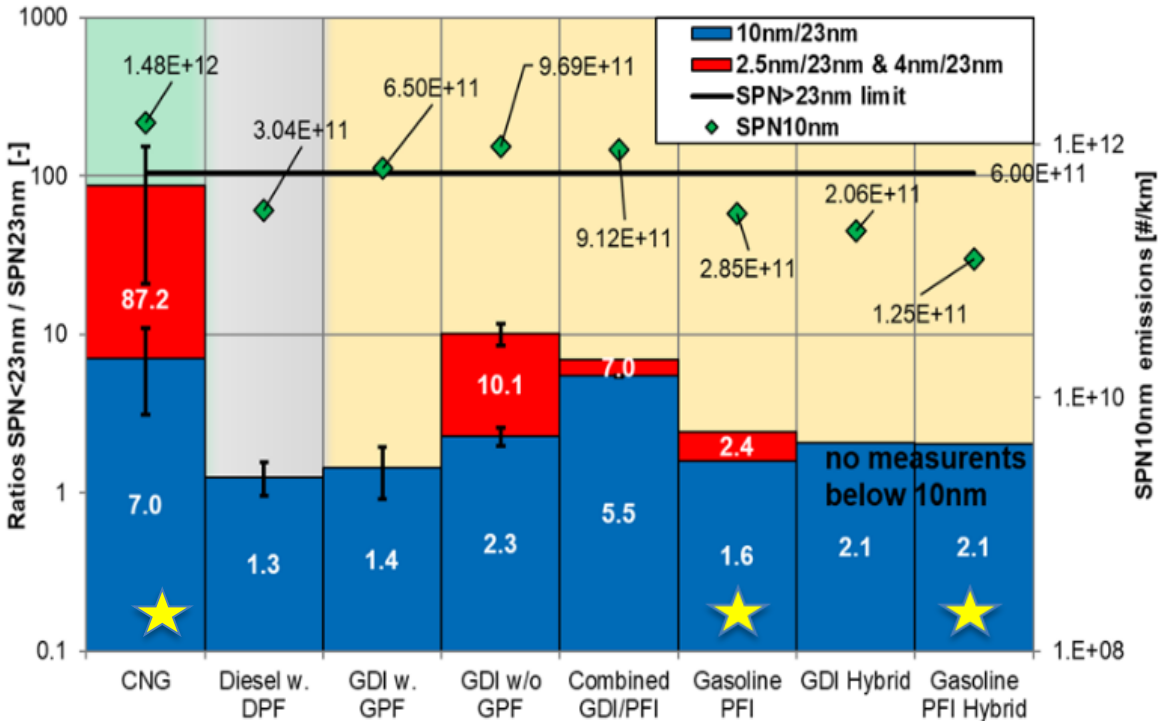
Overview of PN emissions – vehicle segments and methodology



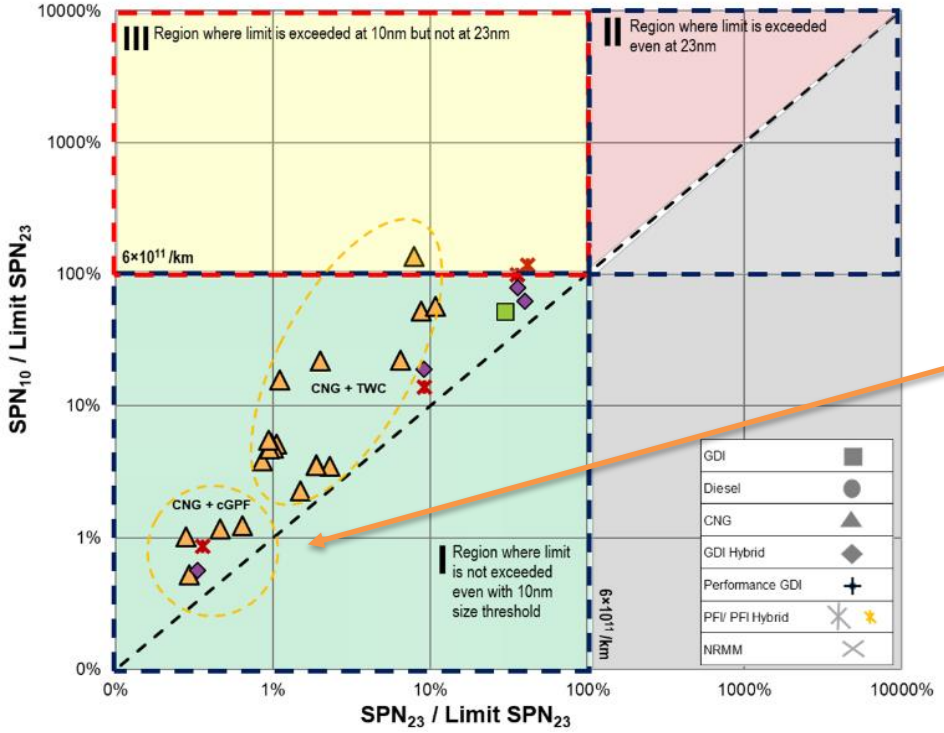
- Engine technologies / aftertreatment combinations (including 6d-temp and final light-duty applications)
- Emissions certification standard: At least Euro 5 through to Euro VI-C and Euro 6d-Final
- Regulatory cycles from around the World
- Extreme operation (beyond the velocity, dynamics and temperature boundaries of regulatory cycles)
- Including environmental temperature extremes (down to -10°C, up to 30°C)
- Fuel variations
- SI fuels to >25% Ethanol, and CNG
- CI fuels to 30% biodiesel, and paraffinic diesels

Solid particle ratios over WLTC



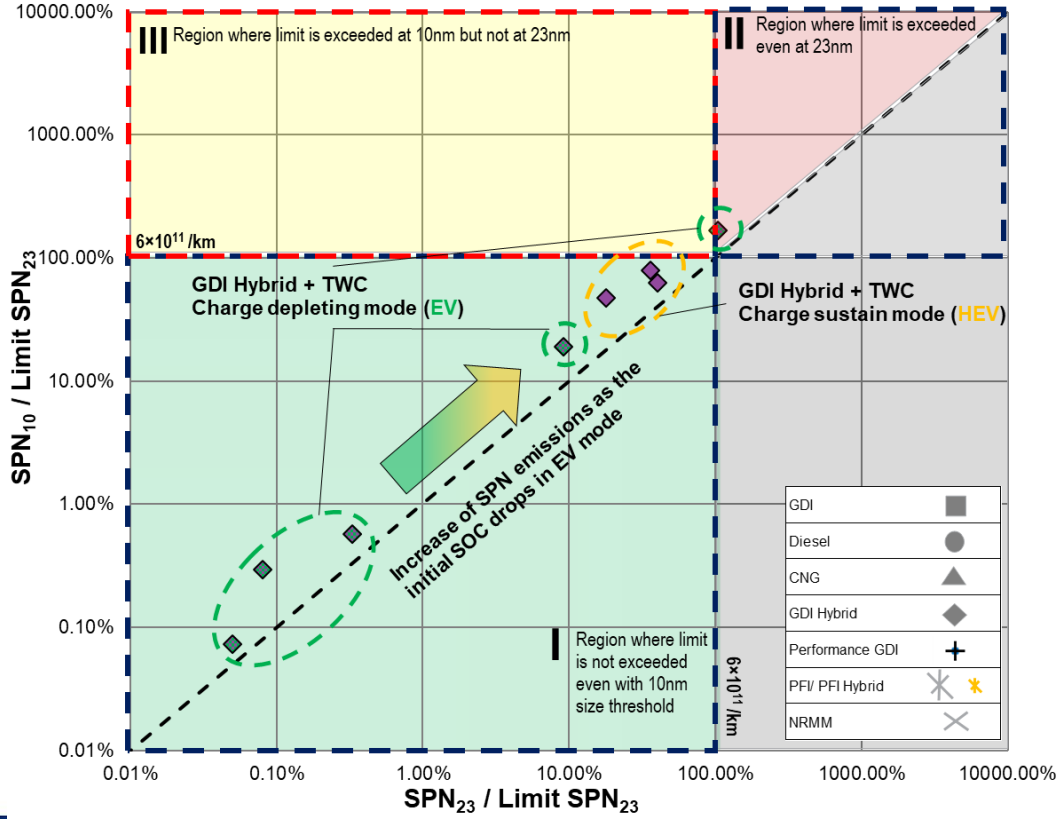
- Error bars show the standard error of the mean from 4 to 13 repetitions. No error bar indicates a unique measurement
- The horizontal bold line corresponds to current GDI and diesel SPN23nm limit (6×10^{11} part/km) and is provided here only as a guide to the eye
- Results indicate high ratios for the CNG and non-GPF GDI vehicles
- Ratios of GPF and DPF equipped vehicles are close to unity due to high filtration efficiency in sub 23 particles (diffusion)
- The asterisk marks those configurations for which the SPN23nm limit is not applicable

CNG and (G)PF



- Implementation of prototype filter, decreased CNG SPN emissions up to 2 orders of magnitude (both SPN10 and SPN23nm)

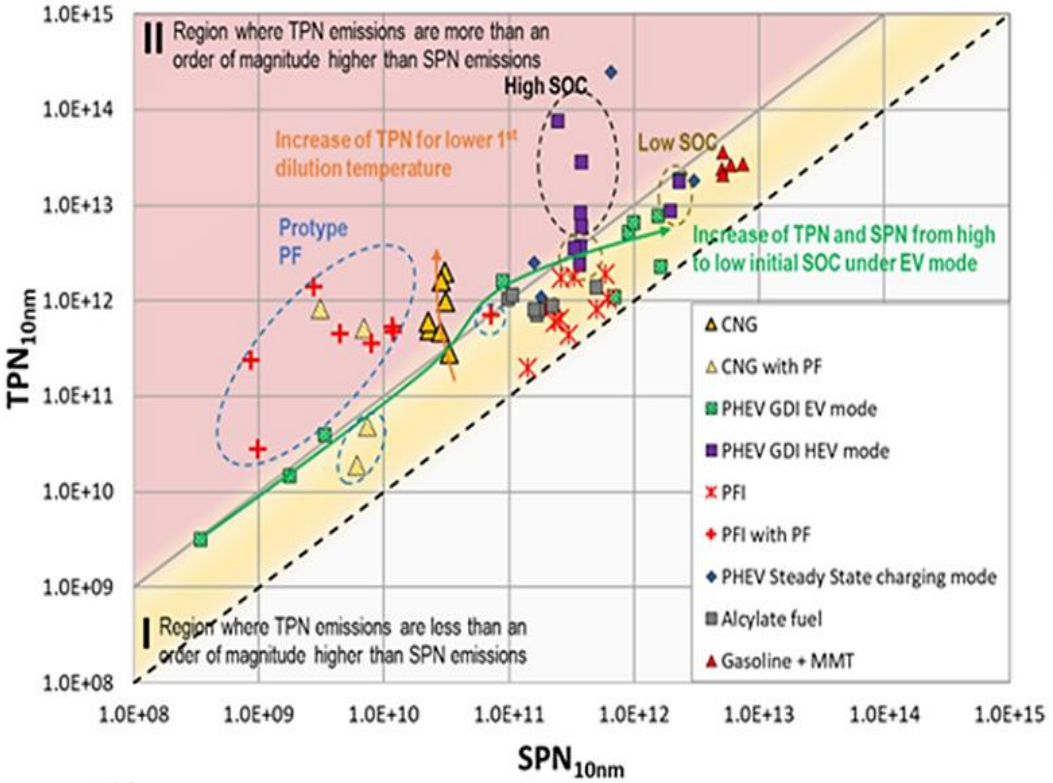
Results from a Euro 6b GDI PHEV (WLTC)

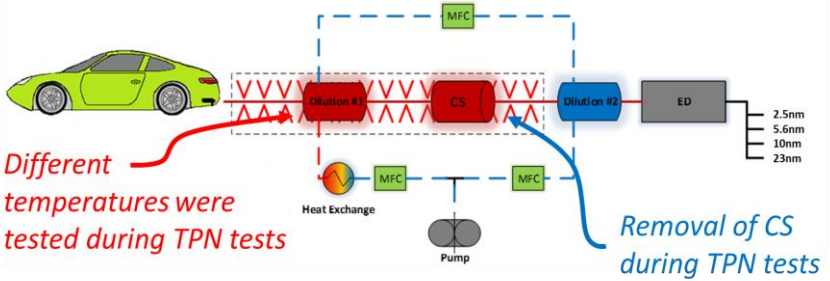


SPN emissions ratio (nm/nm)	10/23	2.5/23
EV	1.9	2.4
HEV	1.7	2.4

- Significant differences between charge depleting and charge sustain mode
- High SPN23 peaks only during cold start in charge sustain operation
- Both SPN23 and SPN10 remain within limits in both modes

Total particle number (TPN) emissions should not be neglected





- Recent technologies seem to lead to significant reductions of TPN
- Generally TPN10 <10x SPN10
- Catalyst warm-up is critical

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Technical conclusions

- SPN<23nm measurement on the road is possible
- Most results below 6×10^{11} km^{-1} down to SPN10
- Potential SPN<23 measurement artefacts, suggest that the DTT PEPS results are only comparable with a raw exhaust lab-based measurement system, rather than the CVS
  - Implications for standardization

Mean ratios over WLTC	SPN_{10}/SPN_{23}	$SPN_{2.5}/SPN_{23}$
CNG	5.9	75.4
CNG + prototype filter	2.5	16.7
GDI	2.1	8.8
PHEV GDI	1.8	2.3
GDI + GPF	1.4	1.8
PFI	1.8	4.0
PFI + prototype filter	1.6	2.7
Diesel + DPF	1.5	1.2
Latest Diesel + DPF Regen	1.6	1.2

Notes

- Summary of measurements conducted by DownToTen partners

Impacts

- DownToTen results are being used to scientifically underpin the Euro 7 emission standard development in the EU
- The sampling system developed may be used to perform RDE-type of measurements of SPN10 and other particle dimensions
- The method developed and the results obtained may be used to
  - Bring in the market clean and efficient vehicle technologies
  - Improve engine and emission control performance with different fuels
  - Characterise size-fractionated particle chemistry to identify the formation mechanisms and control those in a targeted cost-effective fashion

Danke Merci Grazie Gracias

Thank You תודה. Hvala

Dziękuję 謝謝

Ευχαριστώ

감사합니다 ありがとう

شكرا Спасибо Хвала děkuji

Takk Kiitos Tänan Dank U

Mulţumesc