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Effect of low temperature on pollutant emissions of hybrid vehicles: Preliminary studies for Low Temp. TF

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June 5th 2018 – EVE – Geneva

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Current Regulation for cold temperature test

Regulation No. 83

Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements

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	T °C	Cycle	Road-Load	Vehicles	Pollutants
	−7.0 ±3	UDC	Determined at -7 °C or 10% reduction of coast-down time	P.I. including hybrids + information regarding NOx after-treatment for C.I.	HC, CO
	−7.0 ±3	UDC	"	"	THC, CO, CO_2
	−7.0 ±1.7	FTP	Performing coast-down tests and calculating road-load coefficients at -7 °C	Otto-cycle and diesel including multi-fueled, alternative fueled, hybrid electric, and zero emission vehicles	NMHC, CO, CO_2 *
	−6.7	CVS-75	"	Gasoline + information regarding NOx after-treatment for C.I.	CO
	−7.0 ±3	Low+ Medium of WLTC	"	P.I.; C.I.; hybrids	THC, CO, NOx

* CO_2 is analysed and results used for the determination of the vehicle fuel economy. Cold temperature standards apply for CO and NMHC emissions.

Issues under revision by Low Temp. TF

- Cycle
  - Introduction of WLTC → NEDC obsolete
- Criteria pollutants
  - Are NOx, PN, PM, NMHC and CO_2 emissions affected by cold temperature?
- Applicability
  - Are emissions from diesel and **electrified vehicles** affected by cold T?

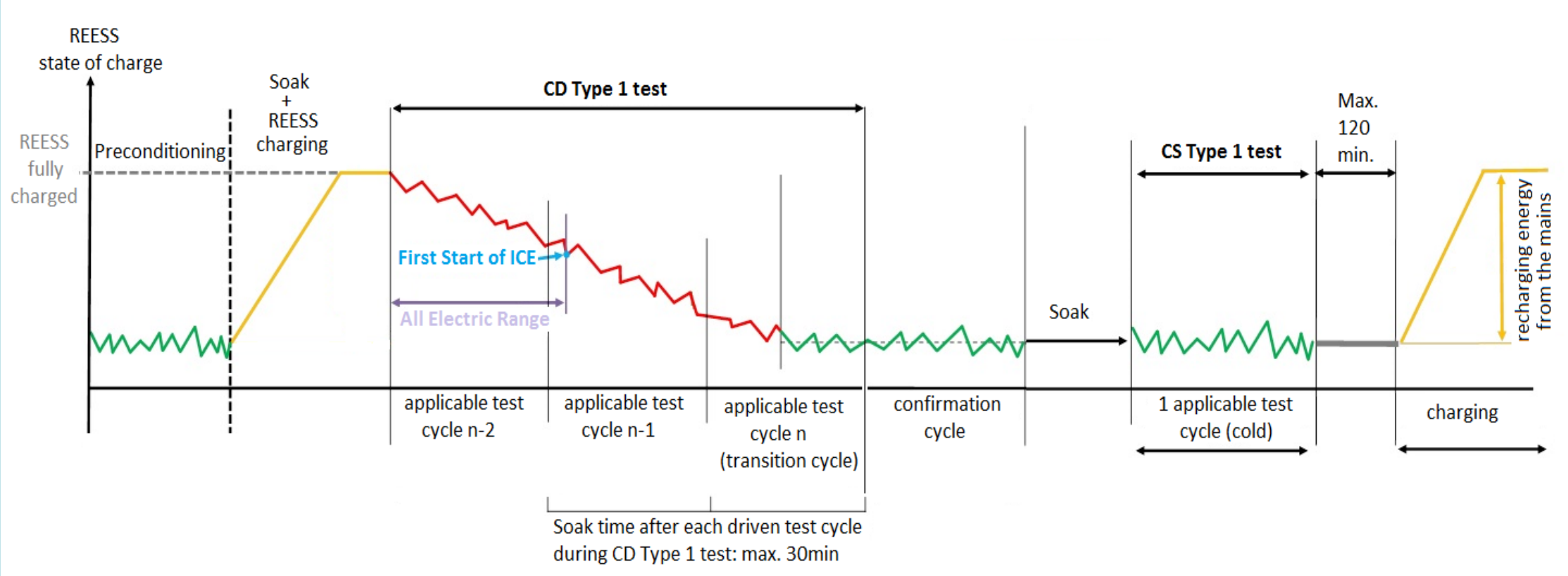
Experimental approach

- Two OVC-HEVs
- Tested following Type 1 procedure at 23 °C and -7 °C
- Road load at -7 °C as described in Type 6 Reg. 83 (i.e. 10% reduction of coast-down time)
- A/C set at 21 °C (U.S. 1066.710 for cold temperature testing)

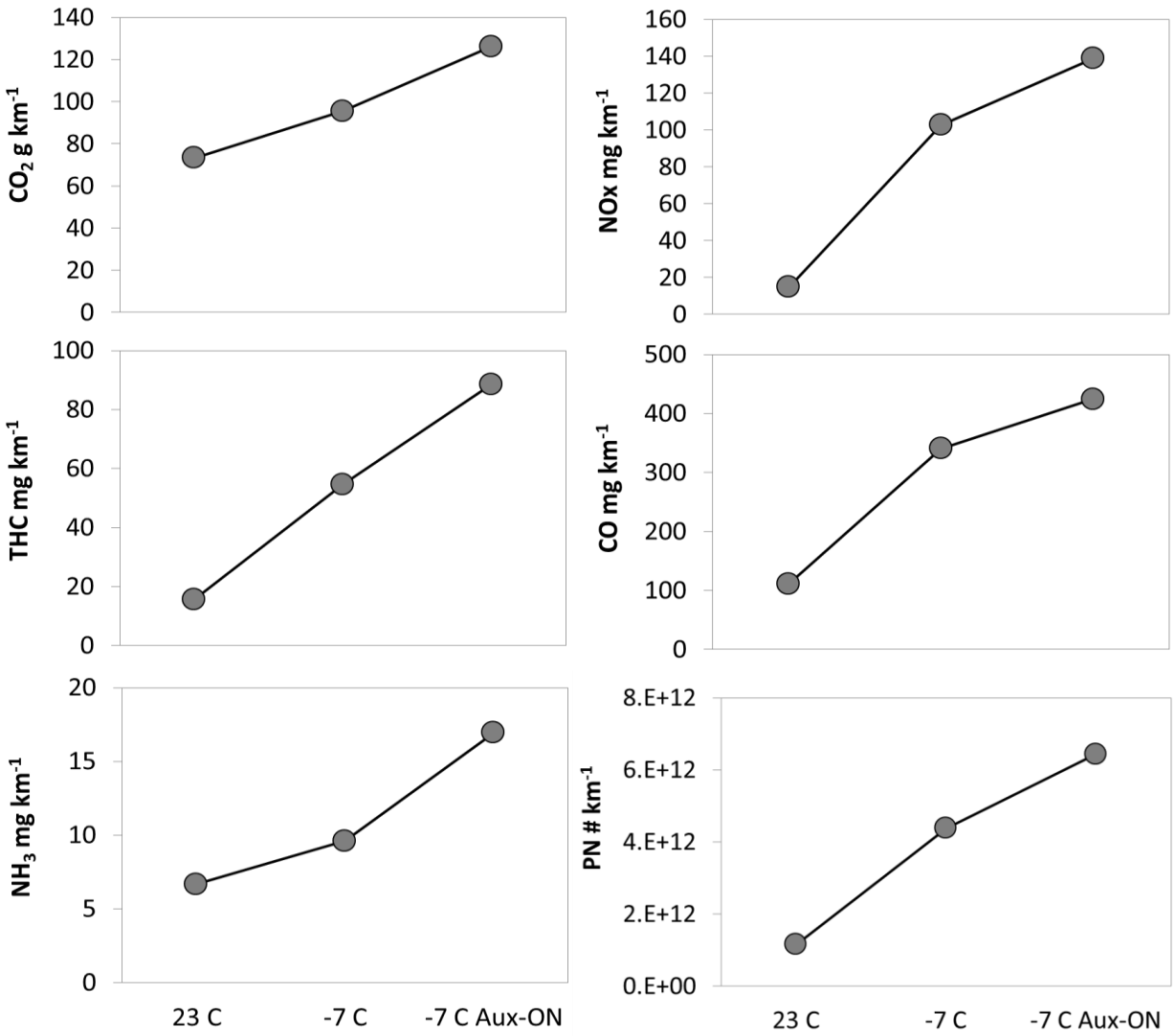
Tested vehicles

	OVC-HEV1	OVC-HEV2
ICE	GDI	PFI
ICE Displacement (l.)	1.4	2.0
Drivetrain layout	Parallel	Parallel/Series
Battery Type	Li-Ion	Li-Ion
Nominal voltage (V)	345	300
Nominal capacity (kWh)	8.7	12
Emission category	Euro 6b	Euro 6b

Test option selected from GTR-15



OVC-HEV1 gaseous & particulate emissions



Higher emissions at lower T

- CO_2: 30% higher
- NOx: 7 times higher
- THC: 4 times higher
- CO: 3 times higher
- NH_3: 50% higher
- PN: 4 times higher

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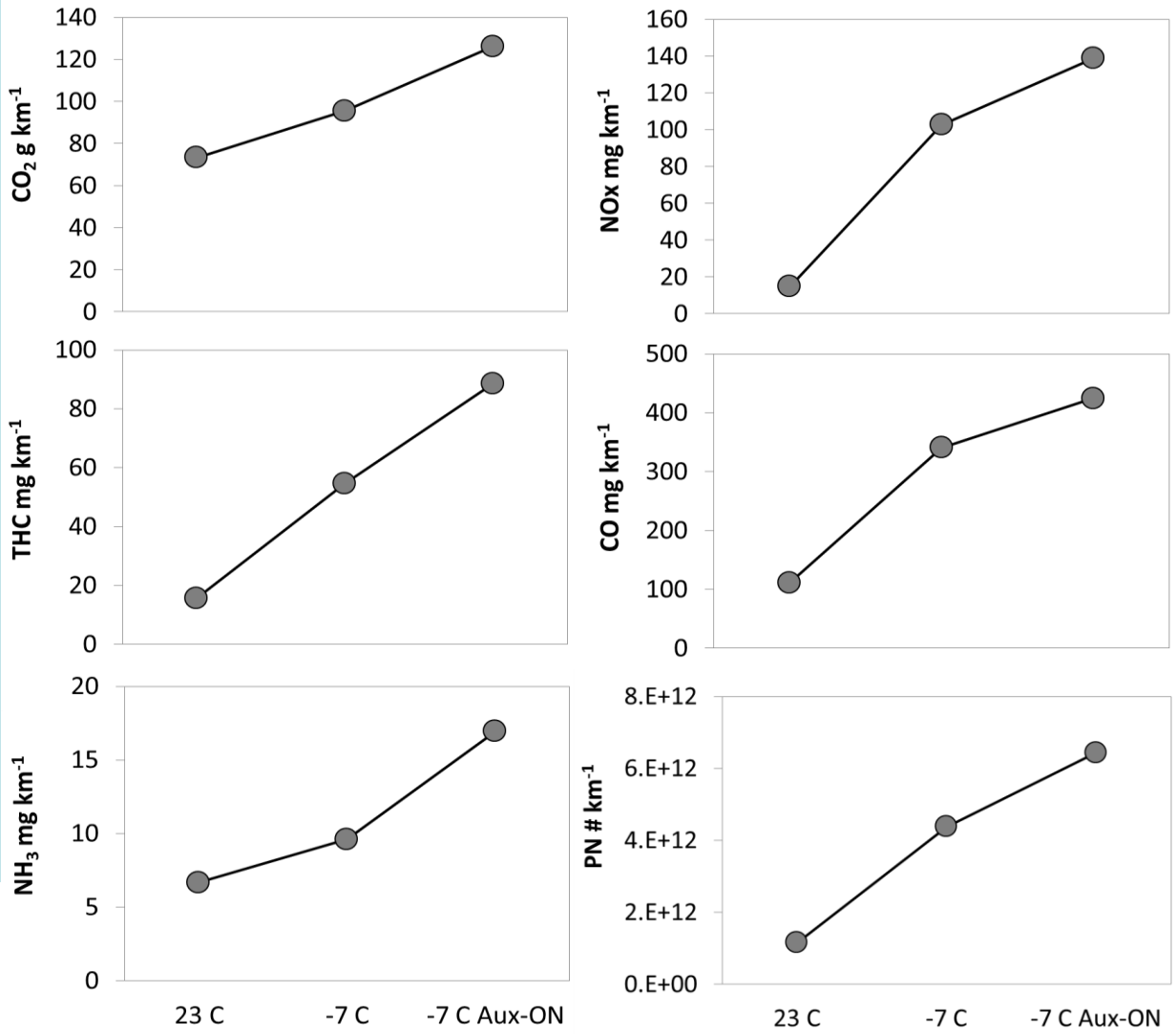
OVC-HEV1 gaseous & particulate emissions



Emissions even higher when heating-ON

- CO_2: 72% higher
- NOx: 9 times higher
- THC: 6 times higher
- CO: 4 times higher
- NH_3: 2.5 times higher
- PN: 5.3 times higher

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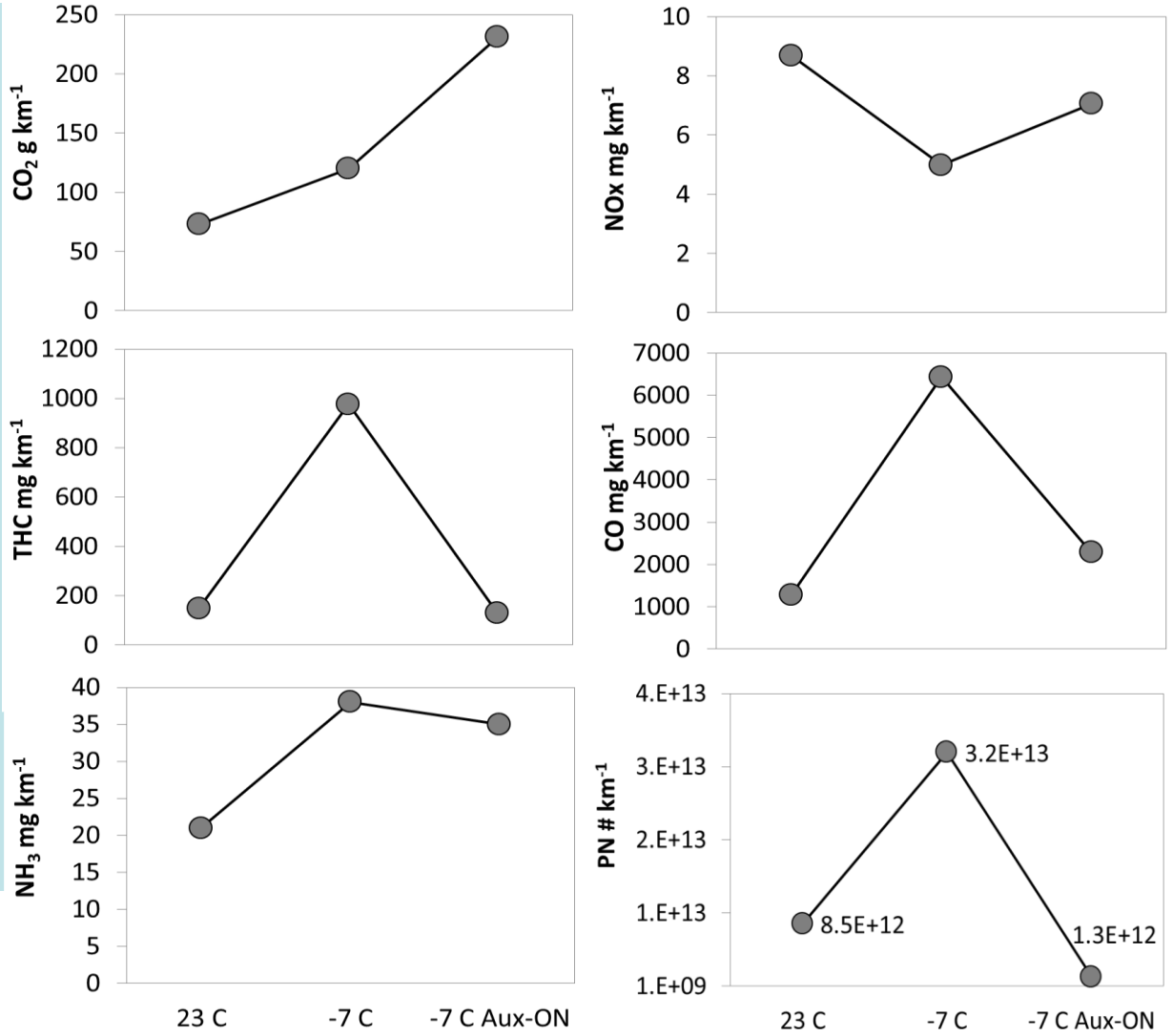
OVC-HEV2 gaseous & particulate emissions



Higher emissions at lower T

- CO_2: 60% higher
- THC: 7 times higher
- CO: 5 times higher
- NH_3: 2 times higher
- PN: 4 times higher
- NOx: 2 times lower

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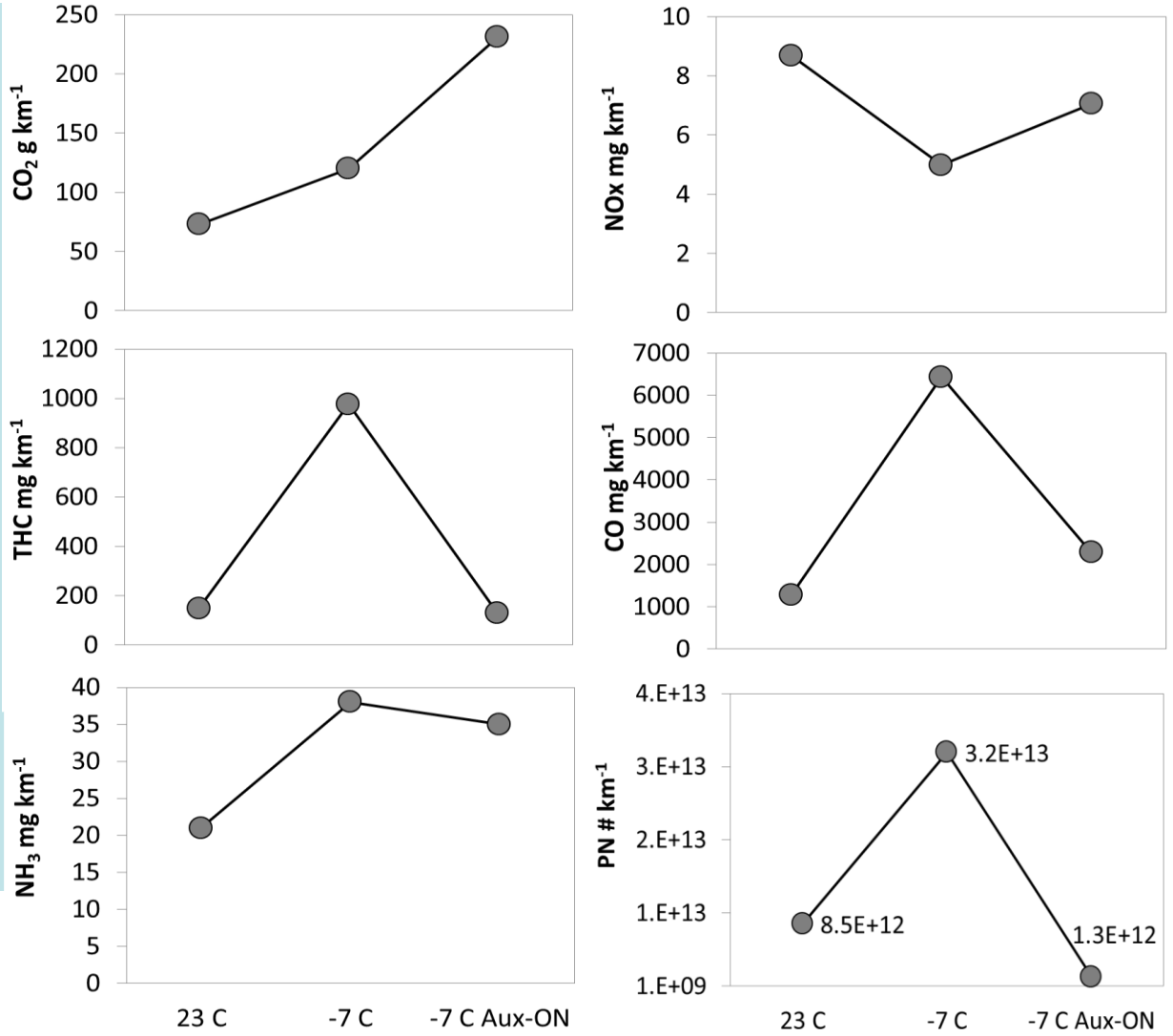
OVC-HEV2 gaseous & particulate emissions



Emissions when heating-ON?

- CO_2: 160% higher
- THC: 13% lower
- CO: 85% higher
- NH_3: 70% higher
- NOx: 20% lower
- PN: 6.5 times lower

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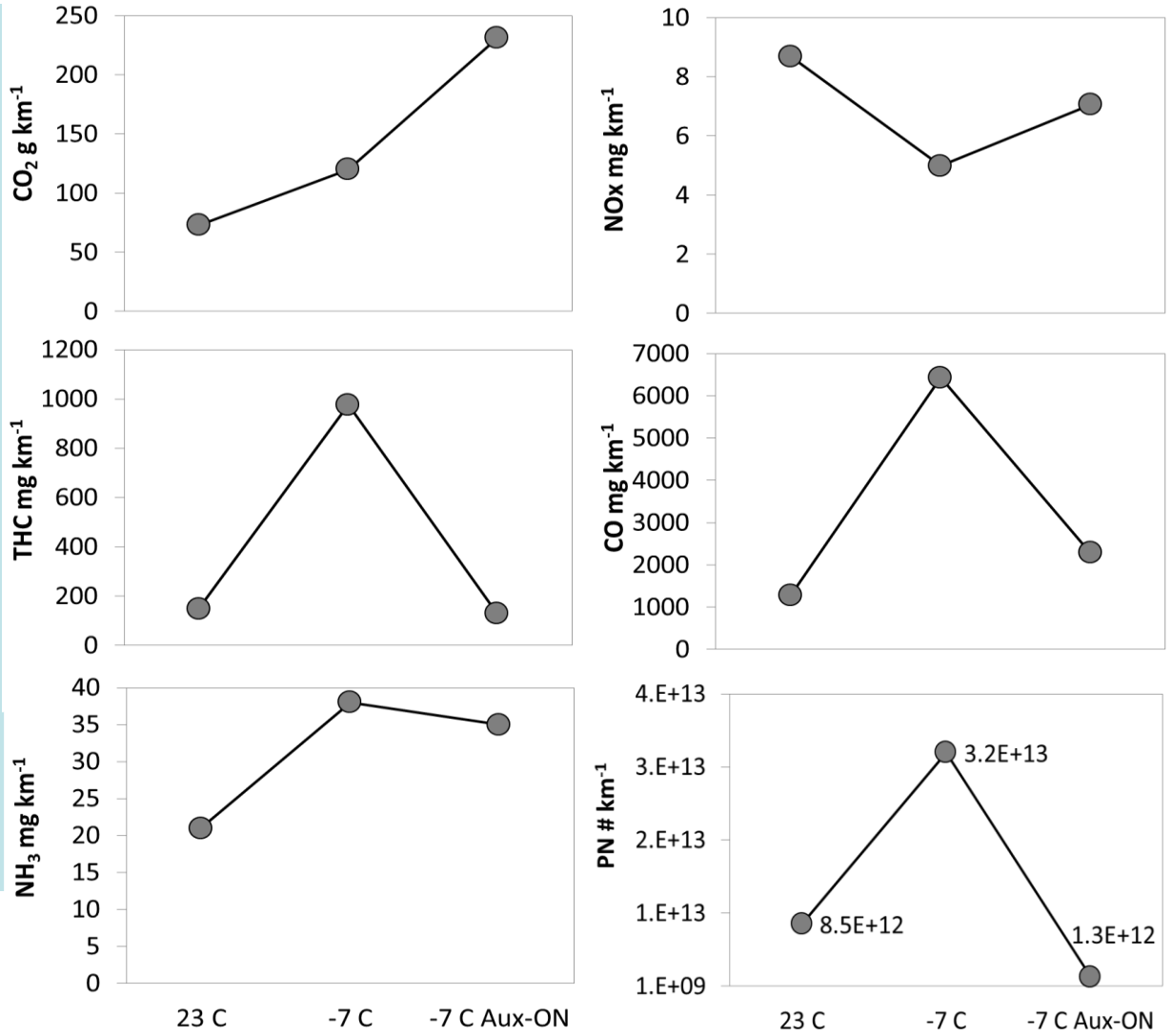
OVC-HEV2 gaseous & particulate emissions



OVC-HEV2 is a **PFI** → EU PN emission standards are not applicable.

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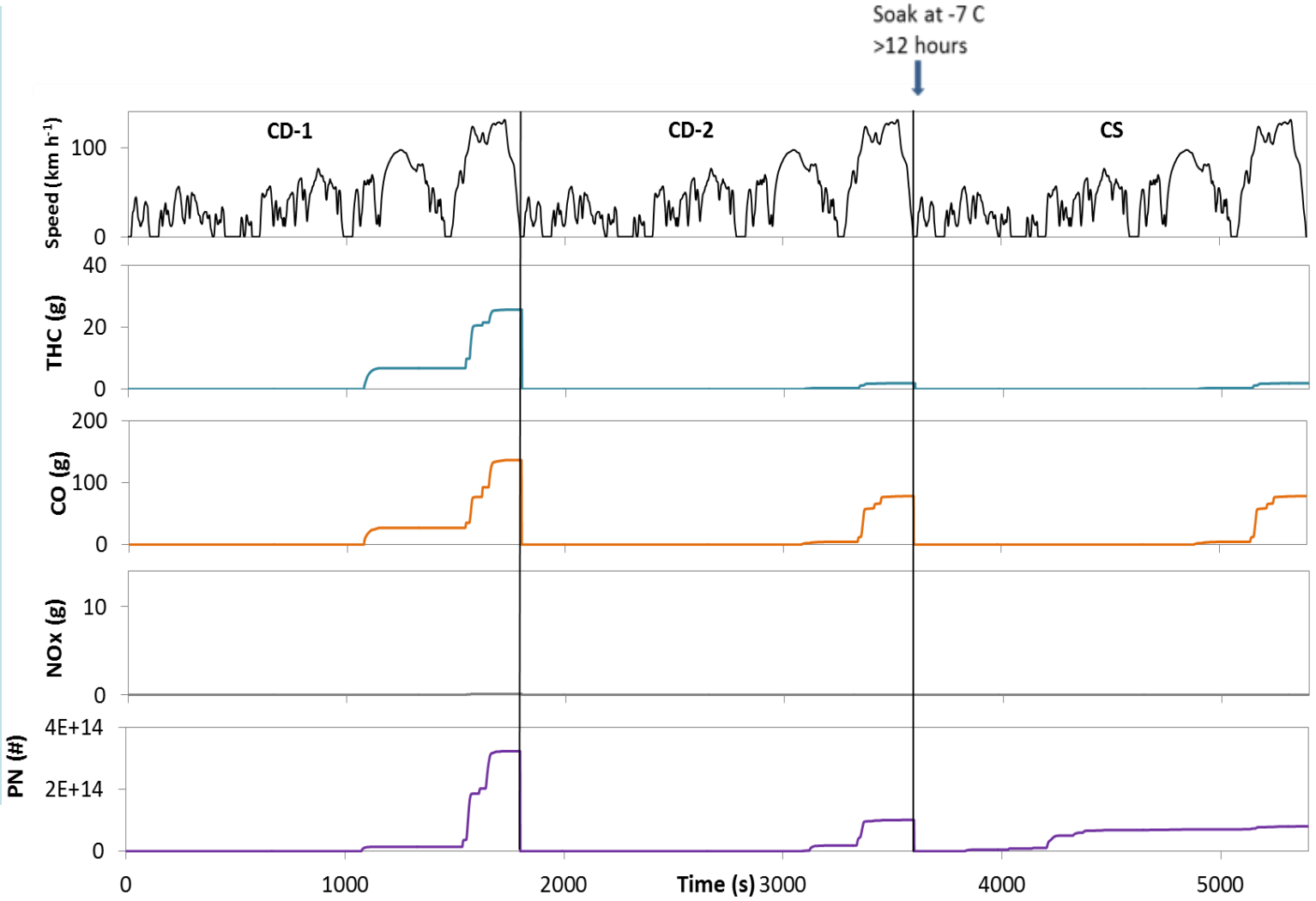
OVC-HEV2 cumulative emissions at -7°C



Total emissions during CD can be **MUCH** higher than during CS test

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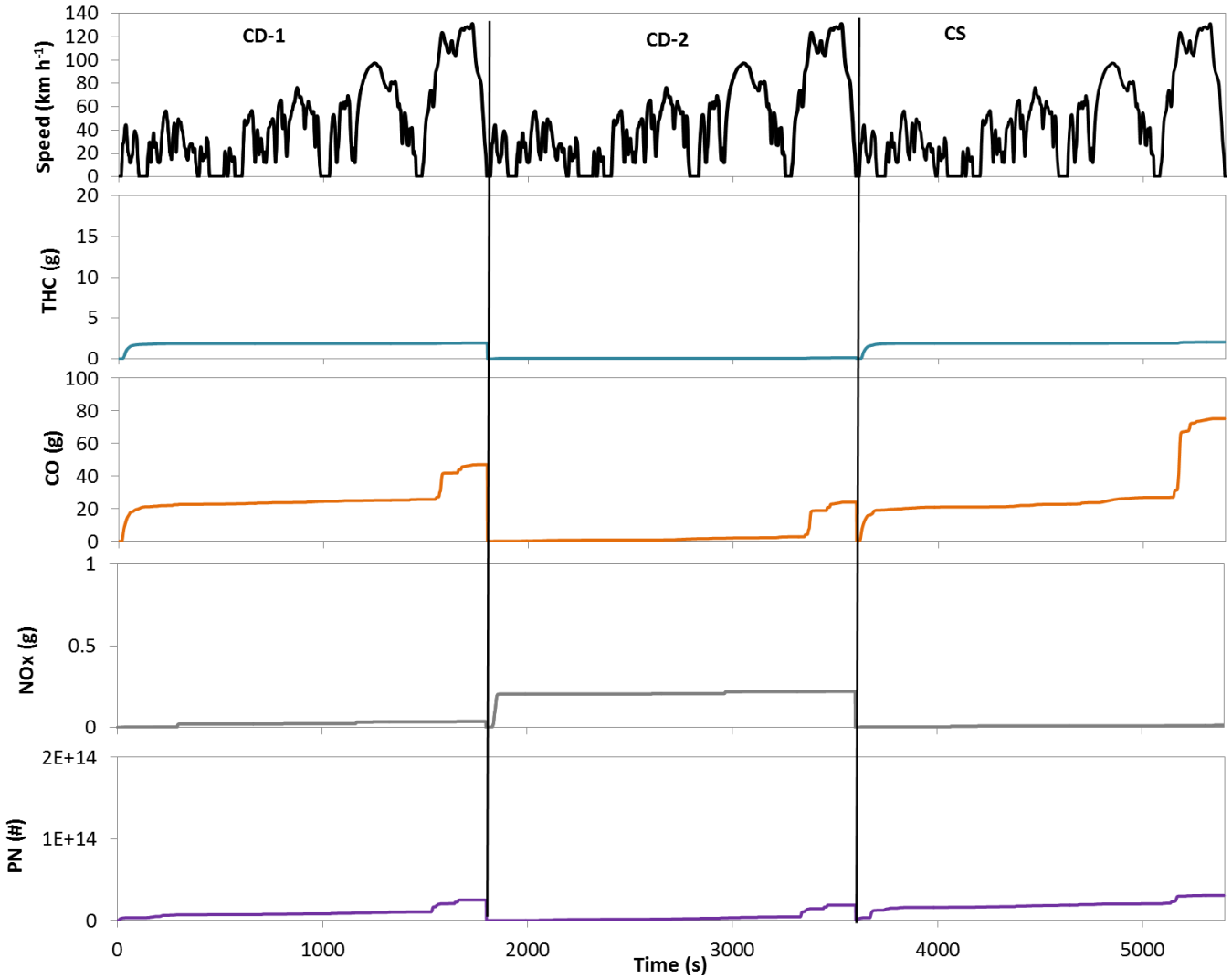
OVC-HEV2 cumulative at -7°C + heating ON



- Engine ignites from start during phase-1 allowing "controlled" heating of the after-treatment.
- This strategy result in an **AER= 0km**

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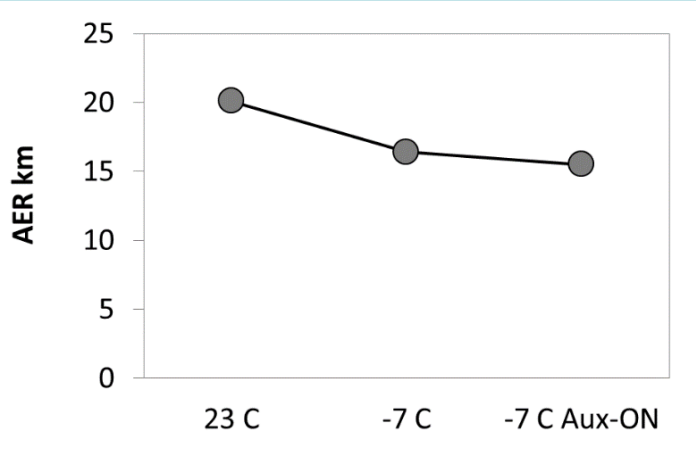
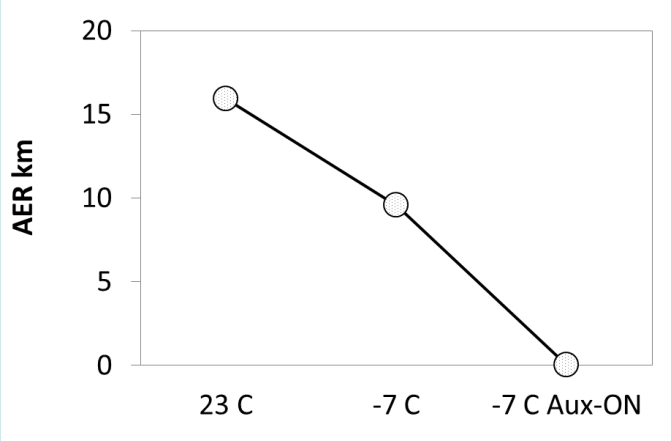
All electric range

OVC-HEV1



OVC-HEV2



- OVC-HEV1 AER decreased 18% and OVC-HEV2 40% at -7°C compared to 23°C

- OVC-HEV2 AER **was 0km at -7°C with heating-ON**
  - OVC-HEV1 decreased 23% at -7°C with heating-ON

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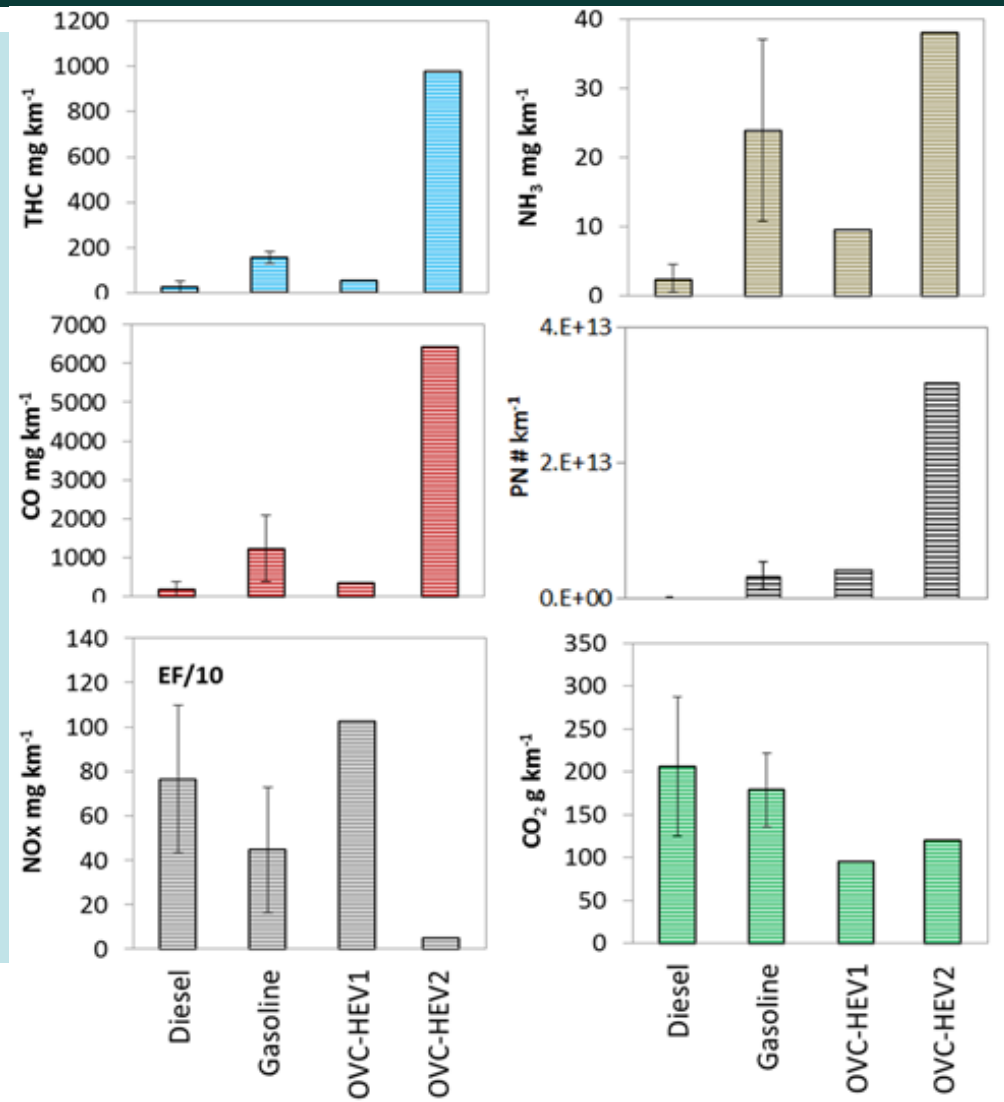
Compared to "pure ICE" vehicles at -7ºC



- OVC-HEV1 emissions are comparable to pure ICE Euro 6b gasoline LDV
  - **NOx higher than the worst gasoline LDV studied**

- OVC-HEV2 (PFI):
  - **THC and CO higher than pure ICE Euro 6b gasoline**
  - **CO_2 slightly lower**
  - **PN 1 order of magnitude higher than pure ICE Euro 6b gasoline vehicles**

Data from diesel and gasoline vehicles can be found at Suarez-Bertoa and Astorga, Impact of cold temperature on Euro 6 passenger car emissions, Environmental Pollution. 234, 318-329. 2018

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Summary

- Emissions from tested vehicles were strongly and negatively affected by cold ambient temperatures
    - Higher emissions at -7 °C than at 23 °C
- High emissions were observed during both CD and CS tests.
- Use of heating system further increased emissions in most cases.
- Emissions from OVC-HEV can be as high as those of “pure ICE”.

Issues to be addressed for OVC-HEVs

- Are emissions affected at cold temperature? **Yes**
- Is CS test enough to fully address OVC-HEV emissions at cold T? **No, CD test also needed**
- Is there a negative impact on emissions if heating system is used? **Yes**
- Is it possible to follow Type 1-like procedure for OVC-HEVs at -7°C? **Yes**

Thank you

Any questions?

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