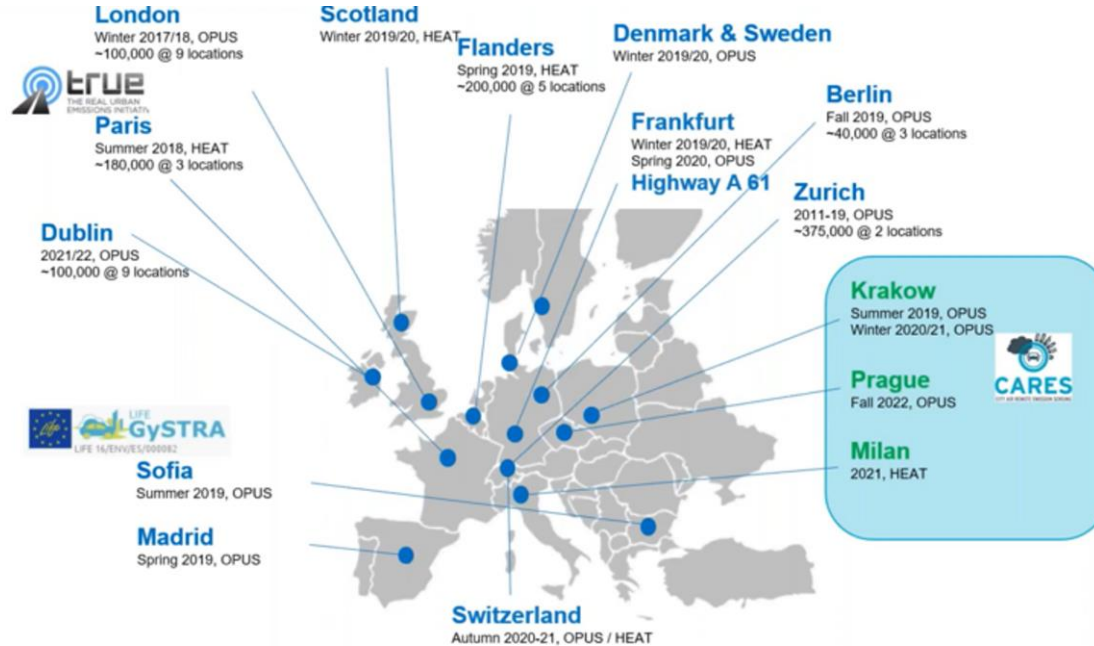


What we can learn from the development and applications of remote emission sensing in Europe over the last couple of years?

Ake Sjodin

IVL Swedish Environmental Research Institute

Europe from a RES perspective 2017-2022



Content

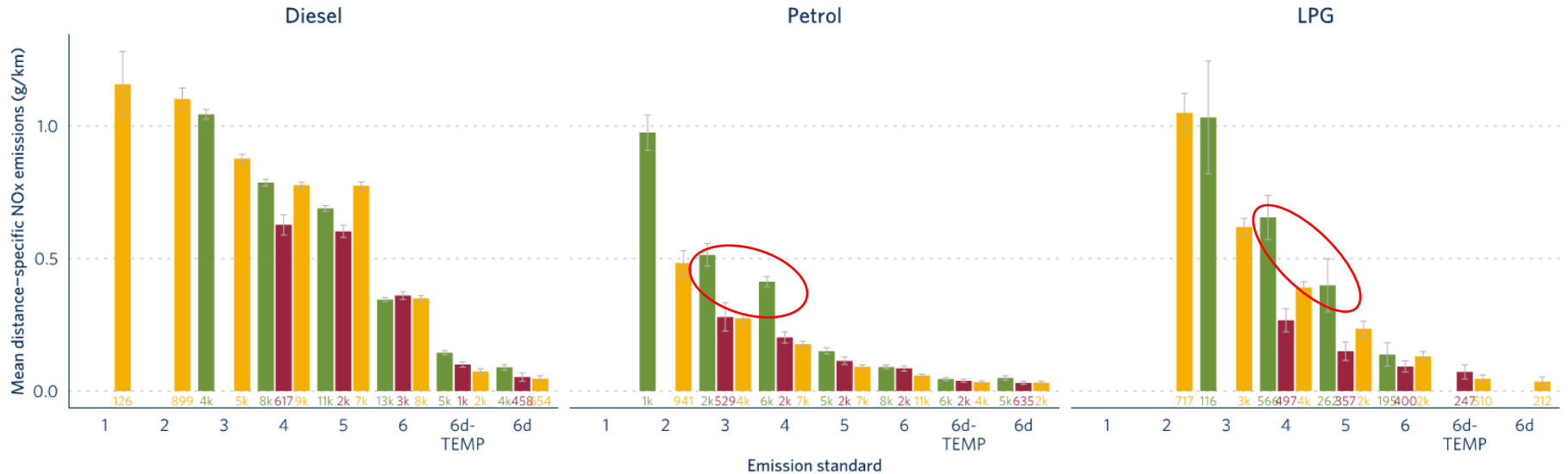
- **Results from RES type 1 measurements**
- Further development and applications of RES type 2
- Further development and applications of RES type 3
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RES type 1 measurements



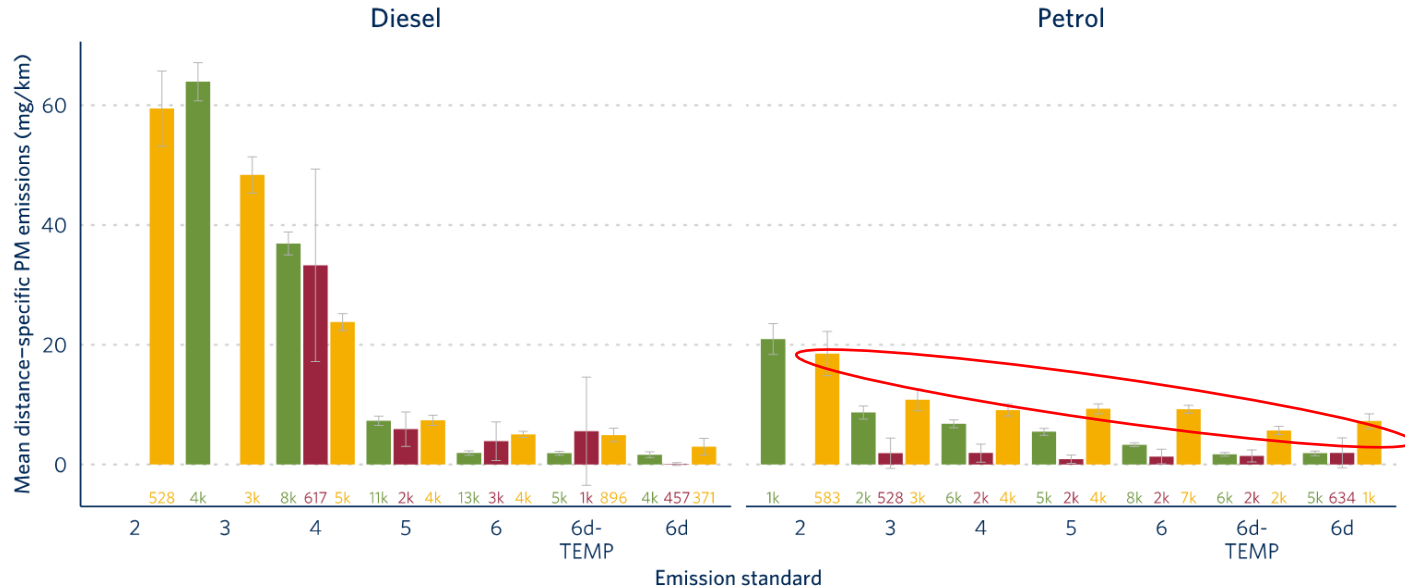
Average **NO_x** emissions for passenger cars by fuel type and Euro standard in three cities



Campaign Prague 2022 Milan 2021 Krakow 2021

REF: CARES project – [report link](#)

Average **PM** emissions for passenger cars by fuel type and Euro standard in three cities



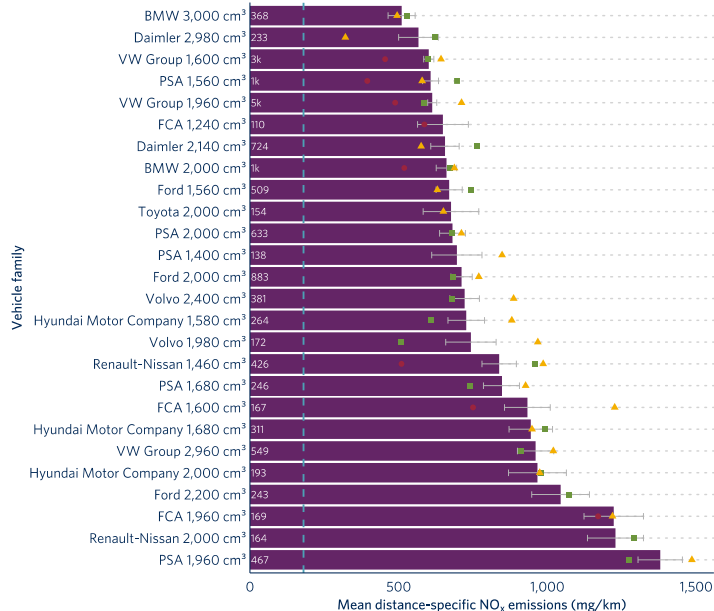
Campaign ■ Prague 2022 ■ Milan 2021 ■ Krakow 2021

REF: CARES project – [report link](#)

NO_x emissions by engine family diesel cars

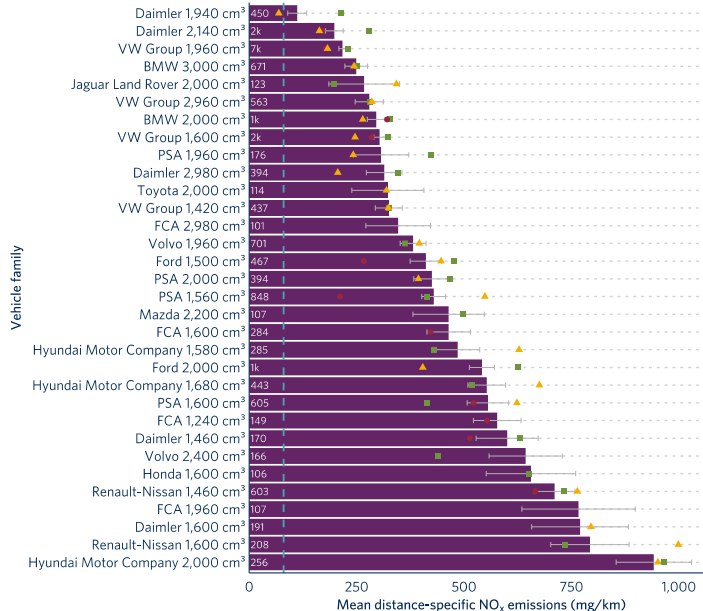
Euro 5 and Euro 6abc

Euro 5: NO_x performance by vehicle family



Campaign ■ Prague 2022 ● Milan 2021 ▲ Krakow 2021

Euro 6a-c: NO_x performance by vehicle family



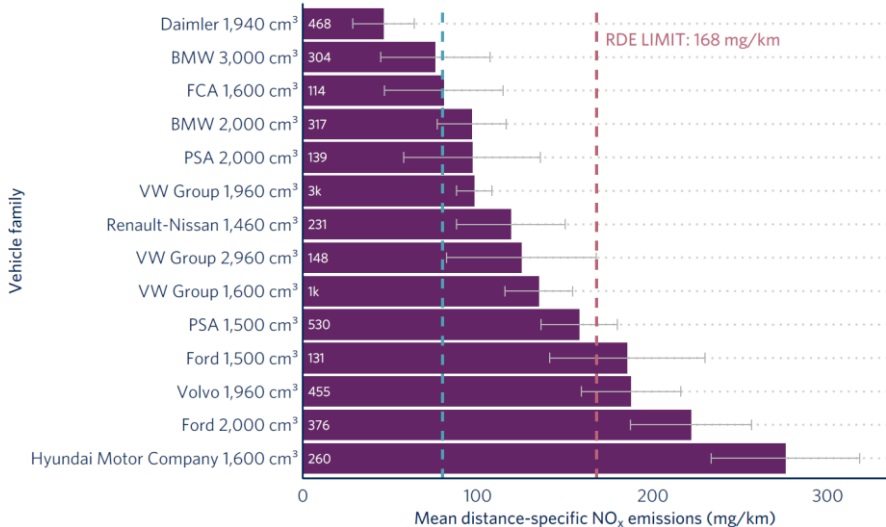
Campaign ■ Prague 2022 ● Milan 2021 ▲ Krakow 2021

REF: CARES project – [report link](#)

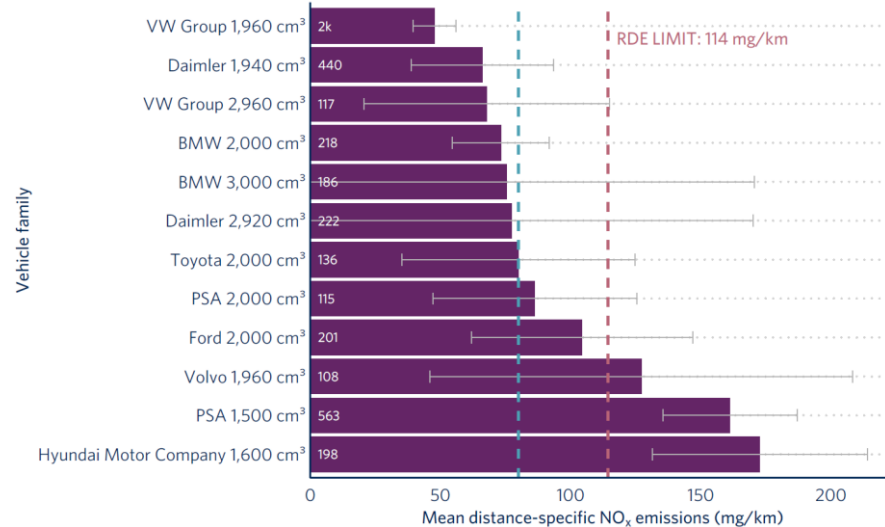
NO_x emissions by engine family diesel cars

Euro 6d-temp and Euro 6d

Euro 6d-TEMP: NO_x performance by vehicle family

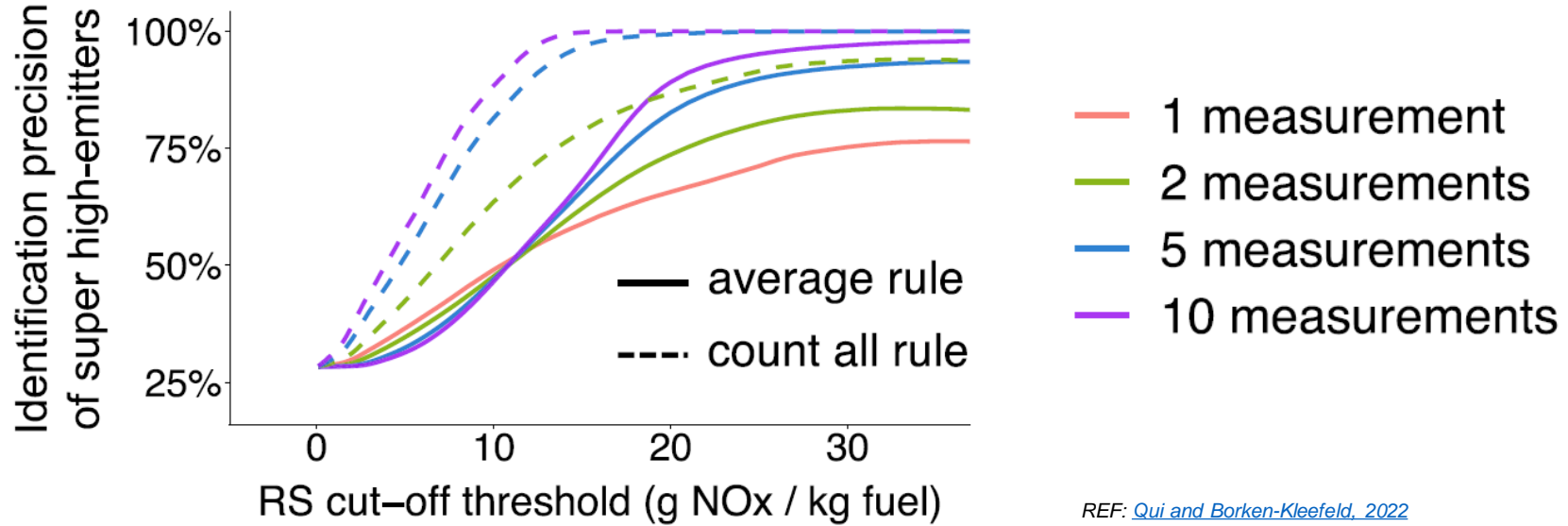


Euro 6d: NO_x performance by vehicle family



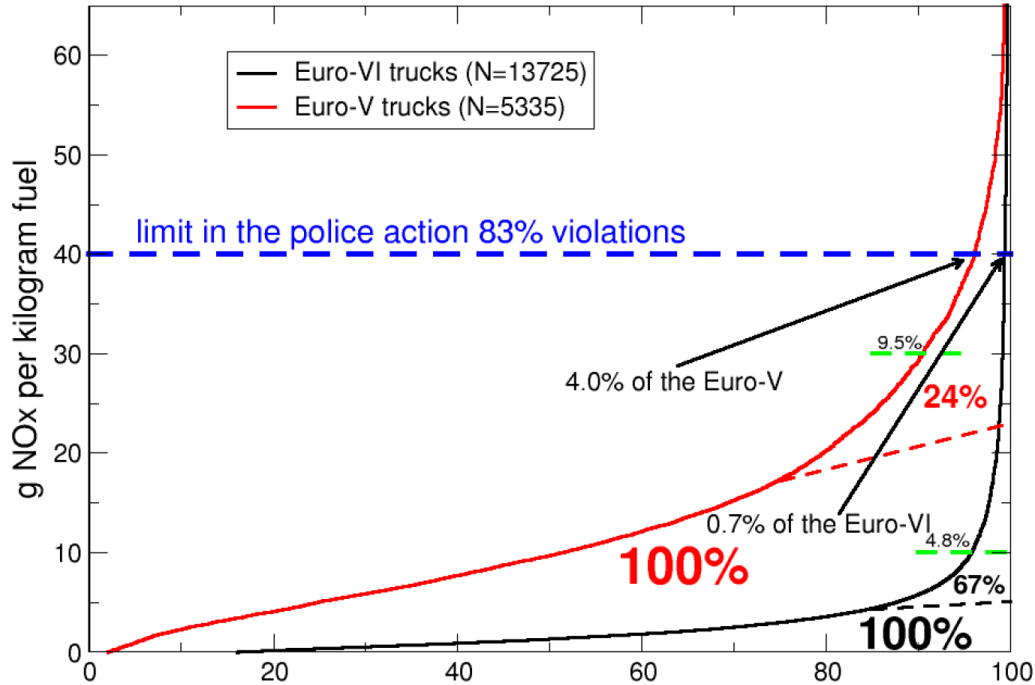
REF: CARES project – [report link](#)

Identification of high-emitting diesel Euro 5 cars



REF: [Qui and Borcken-Kleefeld, 2022](#)

HDV tampering study in Flanders 2019



REF: [Report link](#)

“..... an extraordinarily successful anti-tampering campaign, in which heavy goods vehicles were tested on-road in real-time by EDAR. During these tests, the system’s live interface identified high-emitting trucks that potentially utilized tamper devices based on the truck’s real-time NOx emissions. Subsequently, suspicious trucks were pulled over for a roadside inspection by the federal police. This anti-tampering campaign **increased the tampering detection success rate from 9% to over 83%.**”

Content

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TU Graz RES type 2 sensors

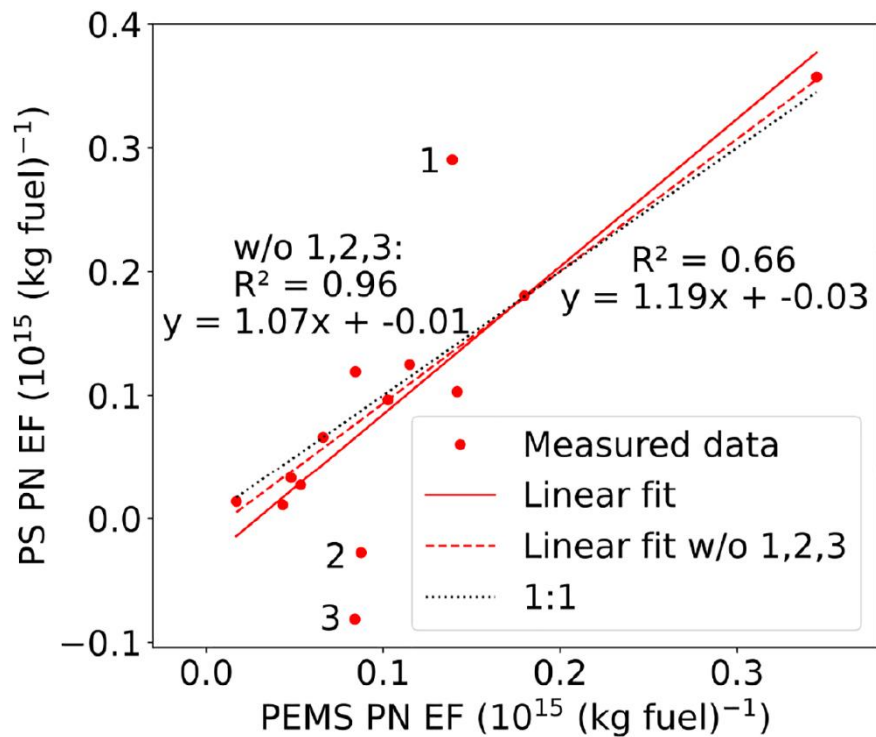
PN (particle number)



BC (black carbon)

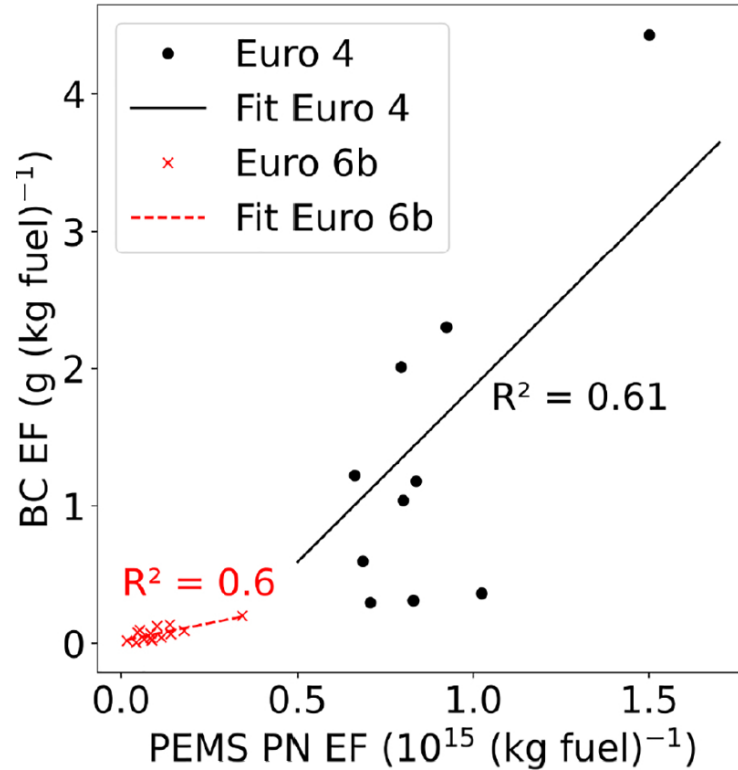


RES type 2 PN comparison with PEMS



REF: [Knoll et al., 2024](#)

RES type 2 BC comparison with PEMS



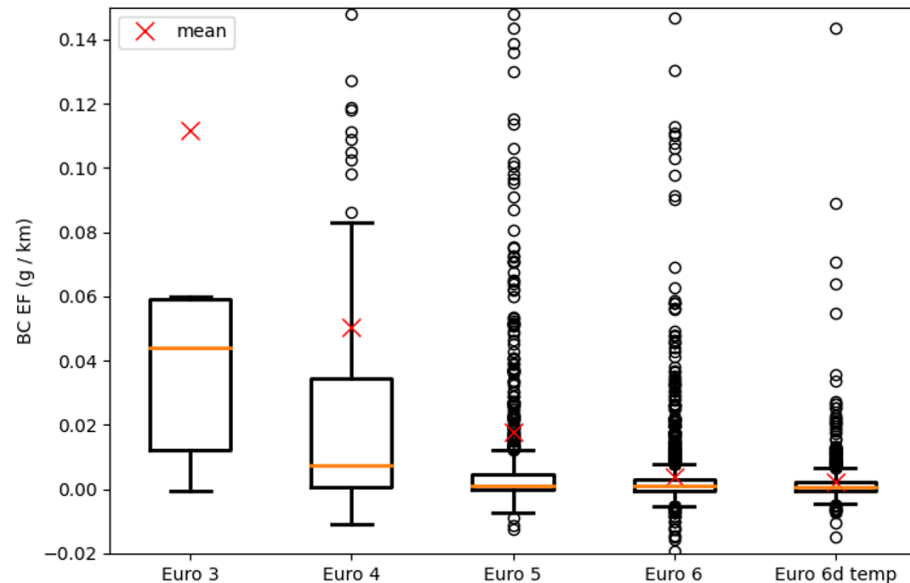
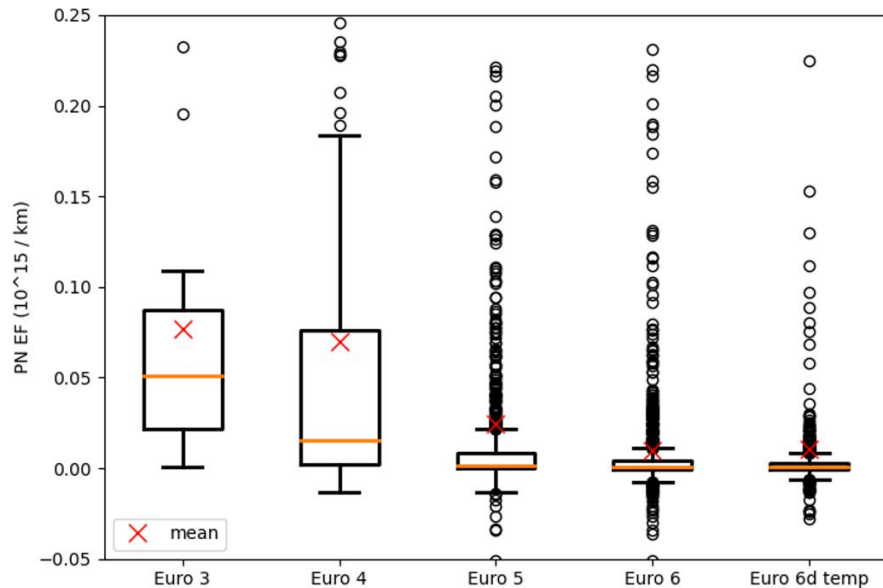
REF: [Knoll et al., 2024](#)

RES type 2 PN and BC emissions by vehicle category, fuel type and Euro class

PN (particle number)

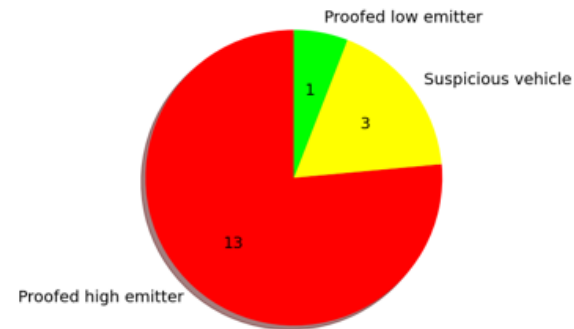
REF: CARES project - [report link](#):
[Knoll et al., 2023](#)

BC (black carbon)



RES type 2 PN measurements to identify high-emitters

Vehicle	Reg. Year	Fuel type	PS BC (g/kg)	PS PN (10 ¹⁴ /kg)	INSPECTION PN (#/cm ³)	Inspection comment
FORD Transit	2008	Diesel	-	-	3,00E+06	Missing ANPR detection
MAN TGL 12.250	2011	Diesel	-	-	9,00E+07	Missing license plate information
FIAT Doblo	2014	Diesel	0,43	77	9,00E+06	Expired technical inspection
FORD Transit	tbd	Diesel	0,65	62	3,00E+07	
FORD Galaxy	2012	Diesel	2,99	36	-	393k mileage, no working DPF according to inspection, no PN inspection
SKODA Octavia	tbd	Diesel	-	-	3,00E+06	Missing ANPR detection
PEUGEOT 407	2008	Diesel	1,8	39	2,00E+06	
SKODA Superb	tbd	Diesel	-	-	2,30E+06	Vehicles too close for proper plume separation
IVECO Daily	2011	Diesel	-	-	5,00E+06	Missing ANPR detection
VW Transporter	2009	Diesel	1,38	109	1,35E+07	
AUDI A3	tbd	Diesel	-	-	1,40E+07	Missing ANPR detection
MERCEDES BENZ	2001	Diesel	19,51	386	-	Visible smoke during acceleration, no PN inspection
DACIA Logan	2015	Petrol	0,37	4,9	-	No PN inspection
SKODA Octavia	2007	Diesel	0,17	12,4	-	No PN inspection
FORD S-Max	2006	Diesel	2,78	63,2	-	No PN inspection
HYUNDAI i30	tbd	Petrol	-	-	4,50E+04	No high emitter, vehicles too close for proper plume separation



REF: [Presentation link](#)

PTI inspection limit PN: **250'000 - 1'000'000 # per cm³ (Euro 5, 6 Diesel)**
 RDE limit: 250'000 # per cm³ ⇔ PN 1,5 * 6*10¹¹ # per km ⇔ 1,8*10¹³ # per kg fuel
 PS threshold (tentative): **> 1*10¹⁴ # per kg fuel , incl. safety margin**



Content

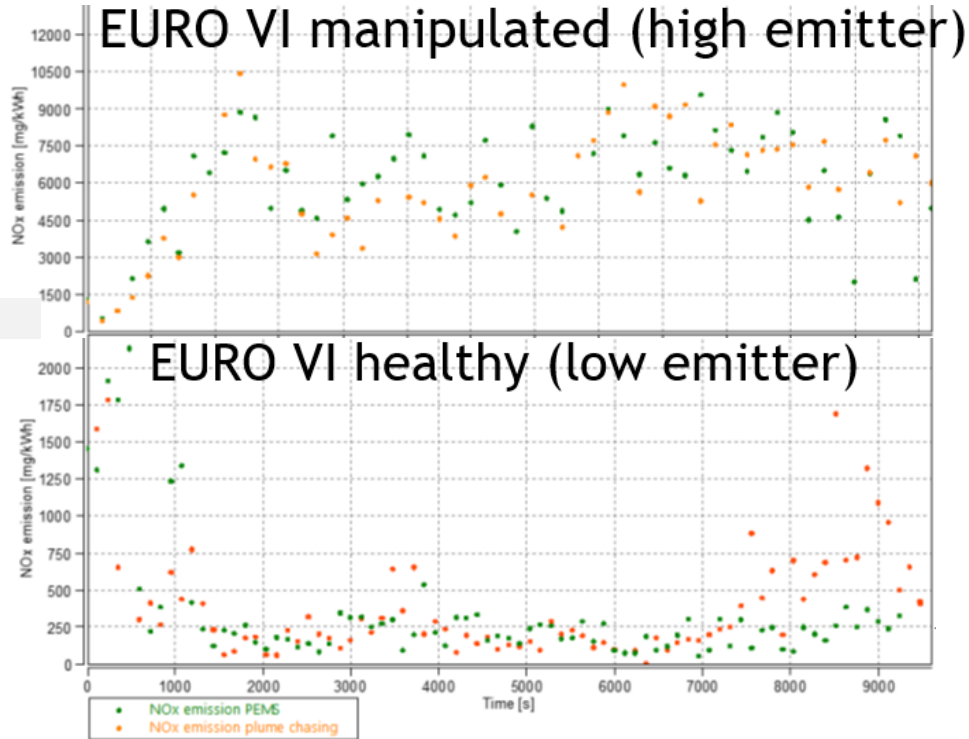
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Airyx/Uni Heidelberg RES type 3 development



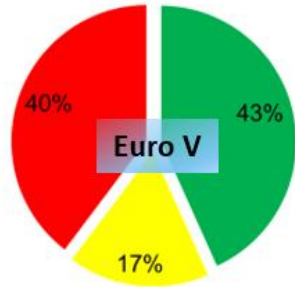
RES type 3 vs PEMS NO_x comparison



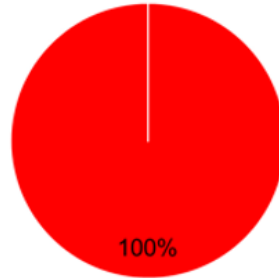
REF: [Presentation link](#)

RES type 3 truck tampering detection (Brno, CZ)

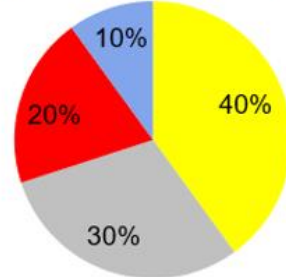
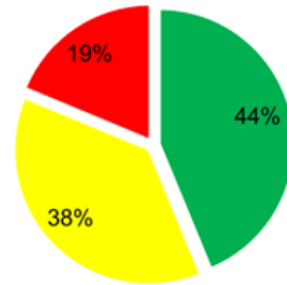
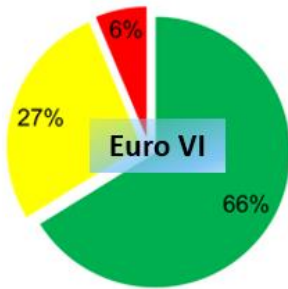
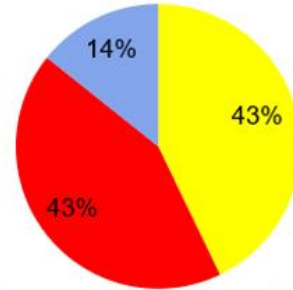
Daytime measurements



Nighttime measurements



Roadside inspections



REF: CARES project – [report link](#)

■ Low ■ Suspicious ■ High

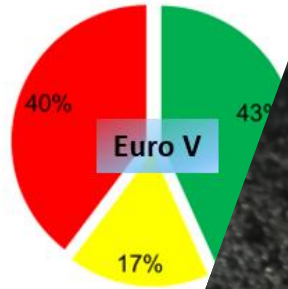
■ Low ■ Suspicious ■ High

■ No Error ■ Defect / Error
 ■ Software issues ■ Manipulated
 ■ Cold SCR

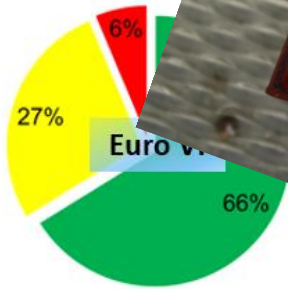


RES type 3 truck tampering detection (Brno, CZ)

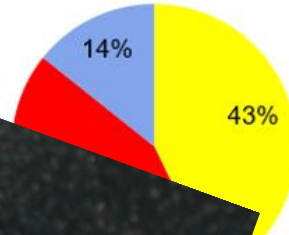
Daytime measurements



Nighttime measurements



Roadside inspections



■ Low ■ Suspicious ■ High

■ Low ■ Suspicious

■ Defect / Error ■ Issues ■ Manipulated

REF: CARES project – [report link](#)



RES type 3 truck tampering detection (Brno, CZ)



Content

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Summary and future perspectives

- For given conditions, all three types of RES are capable of correctly identifying gross-polluting vehicles in real-world traffic
- RES measurements conducted in Europe over the last couple of years confirm that new legislation has resulted in large reductions of both particulate matter and NO_x emissions from diesel vehicles
- Also, RES has become more accurate and cost-effective to use
- A more regular and systematic use of RES, e.g., to support and evaluate ISC, IUC and PTI programs, could be beneficial for European air pollution policy in the future





Thank you for your attention!

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