

# Effect of Tampering on On-Road and Off-Road Diesel Vehicle Emissions

B. Giechaskiel, F. Forloni, G. Baldini,  
A. Melas, G. Fontaras (JRC)

in collaboration with

R. Vermeulen (TNO)  
D. Kontses, P. Fragkiadoulakis, Z. Samaras (LAT)

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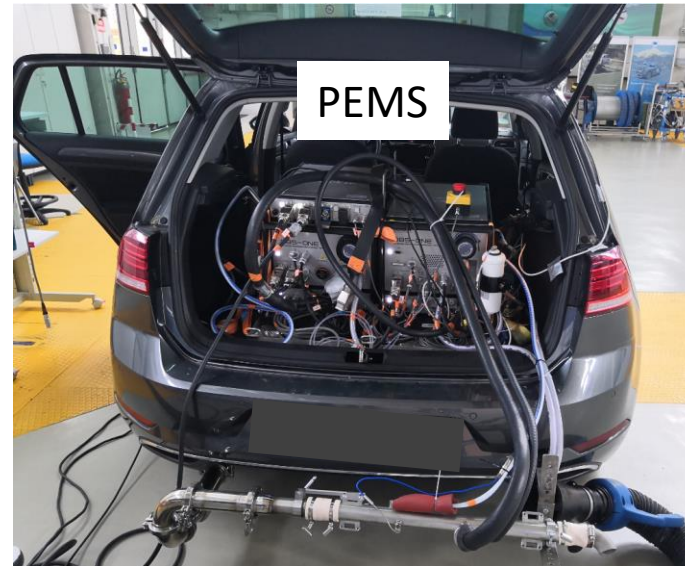
# Outline

- Tampering study
  - Environmental impact of tampering of new generation vehicles
  - Tampering installation costs and savings
- Roadworthiness directives
- PTI (Periodic Technical Inspection) update



# Experimental

- Vehicles: two passenger cars, two trucks, one tractor (all latest technology)
- Test cycles: in laboratory or on road (mostly legislation compliant tests)
- Measurement equipment: laboratory grade or PEMS
- Tampering approaches: ECU flashing, SCR emulators, DPF removal



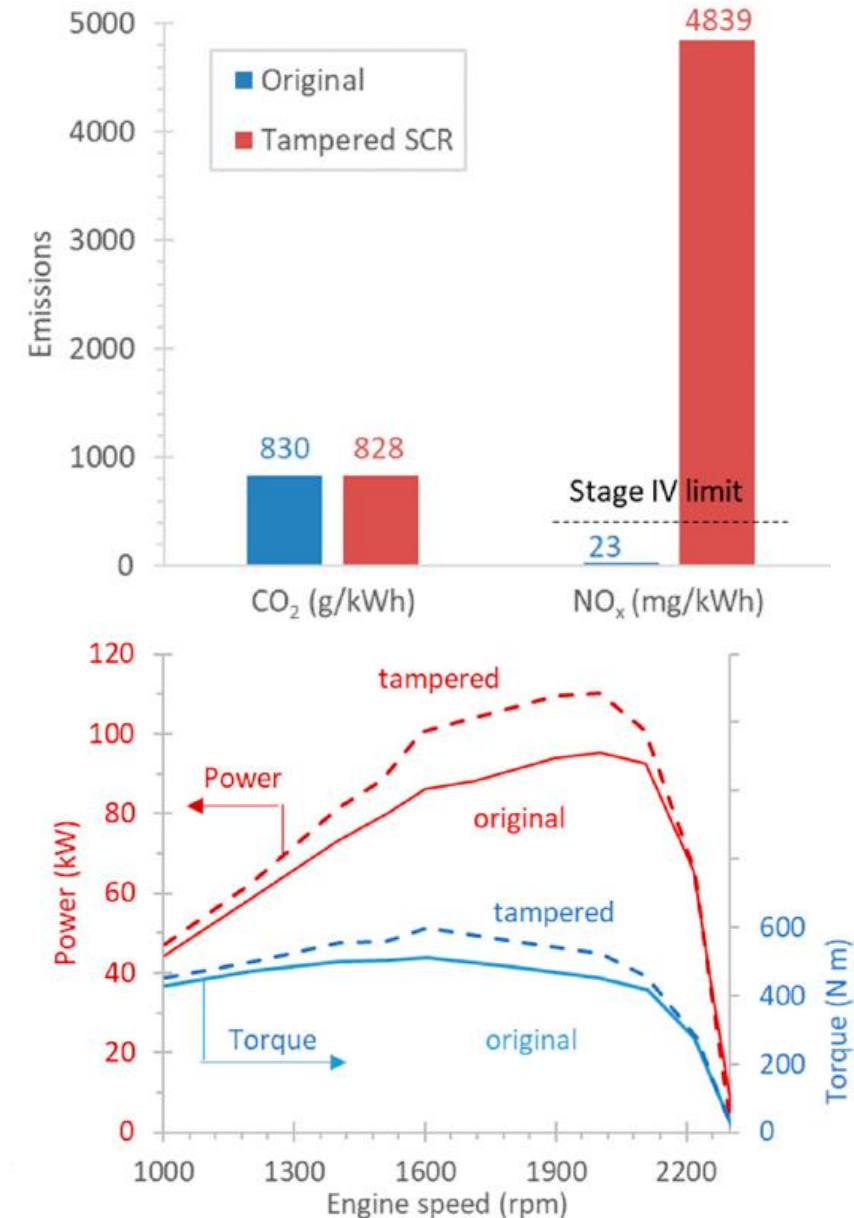
# NRMM Tractor (Stage IV)

## DEF emulator

- Steady point at 50% max power
- NOx exceed >10 times the NOx limit
- NOx reached levels between Stage II and III

## ECU flashing

- 15% increase in power and torque
- Consequences to emissions, safety, durability, drivability were not investigated



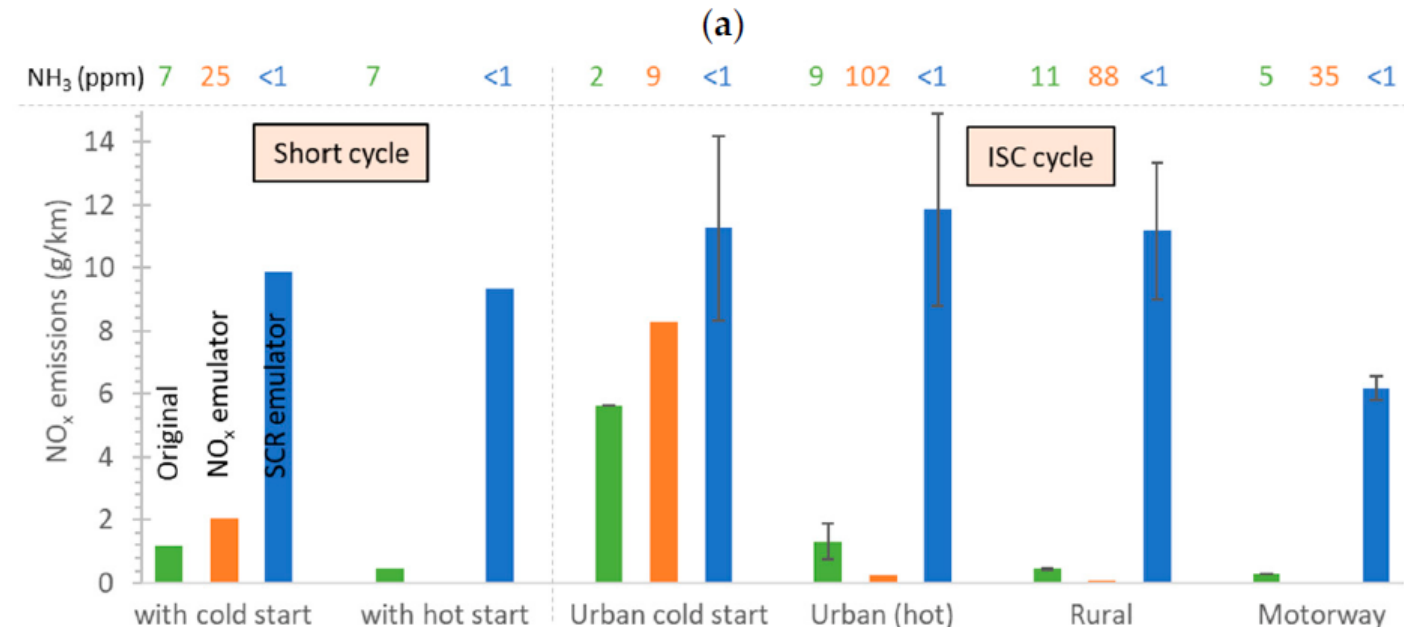
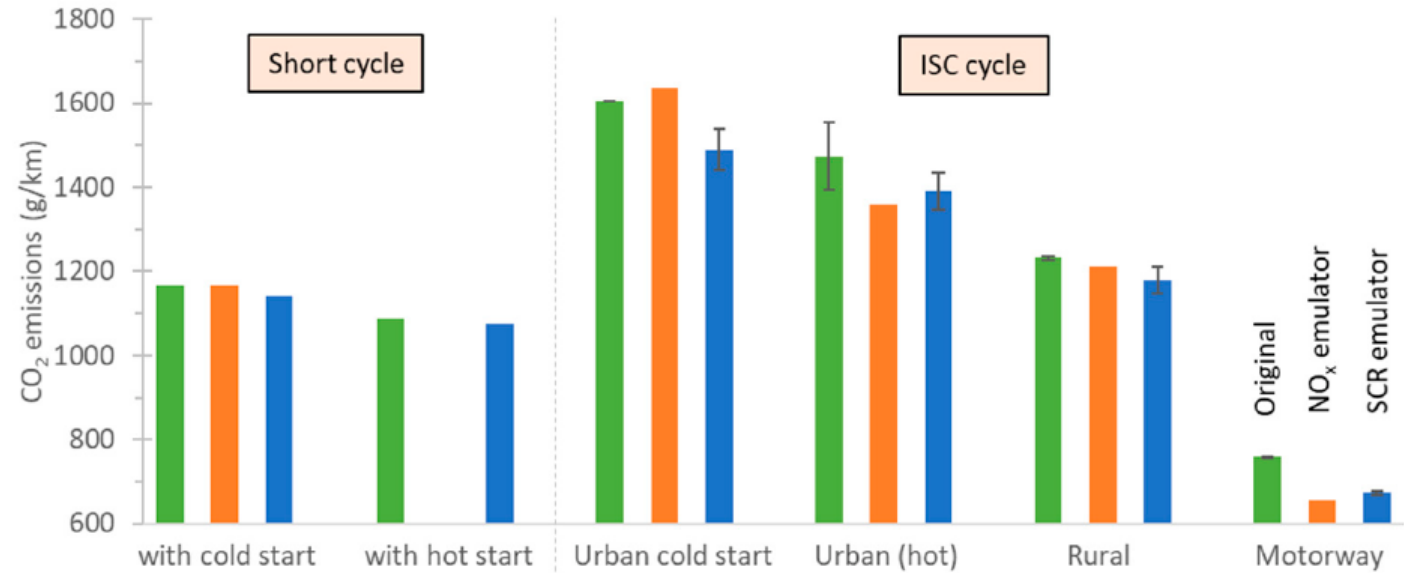
# Heavy-Duty N3 Truck (Euro VI step C)

## NOx emulator

- No impact on NOx
- Increase of NH<sub>3</sub>

## SCR emulator(s)

- CO<sub>2</sub> decrease (but DPF was removed)
- NOx increased
- NOx levels reached between Euro II and Euro III limits
- NH<sub>3</sub> was zero (no urea injection)





# Passenger car (Euro 6d-Temp)

## Tampered EGR

- 3-9% CO<sub>2</sub> reduction

## Tampered SCR

- No CO<sub>2</sub> impact

## Tampered SCR+DPF

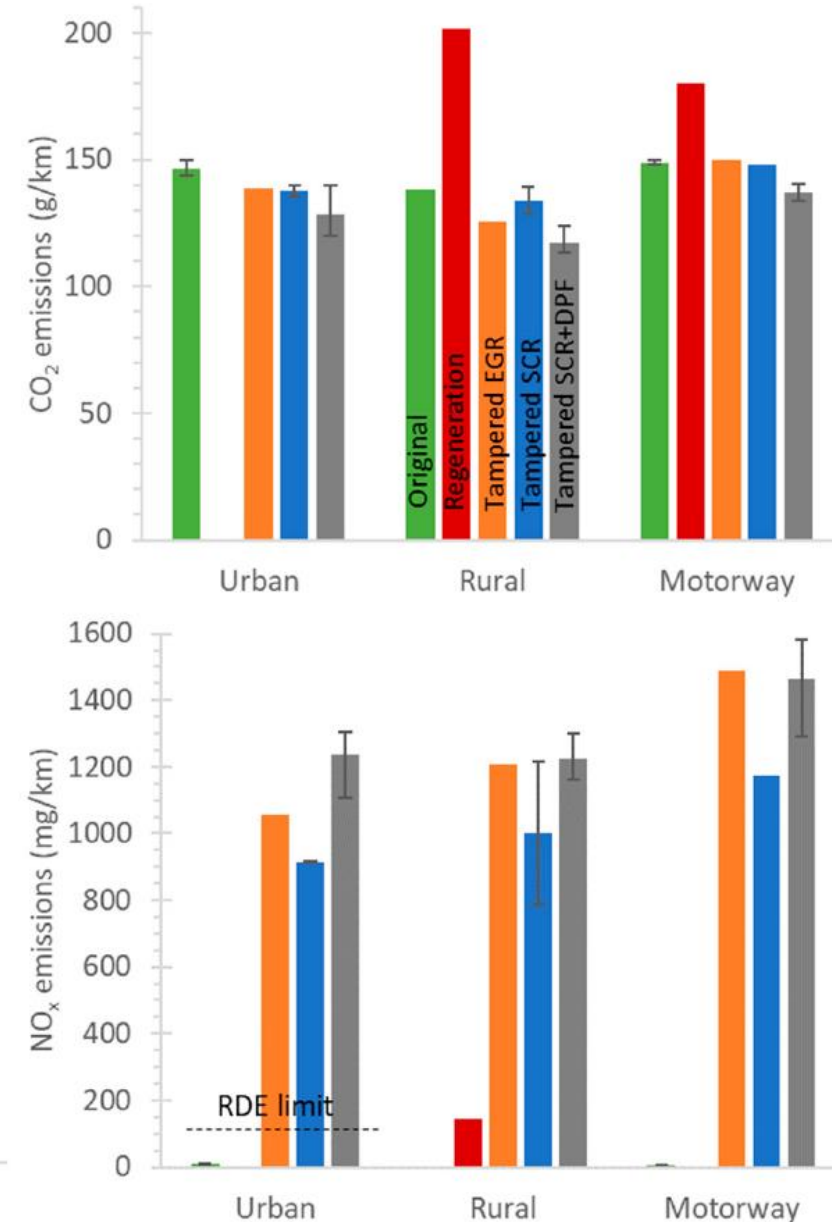
- 8-15% CO<sub>2</sub> reduction

## Regeneration (original)

- 20-45% CO<sub>2</sub> penalty (2.4-3% over regen. Distance)

In all tampering cases NO<sub>x</sub> emissions **exceeded 10 times** the Euro 6 limit, **and reached the Euro 1 limit**

NO<sub>x</sub> increased during regeneration but remained below the Euro 6 limit



# Passenger car (Euro 6d-Temp)

## Tampered EGR

- No impact on PN

## Tampered SCR

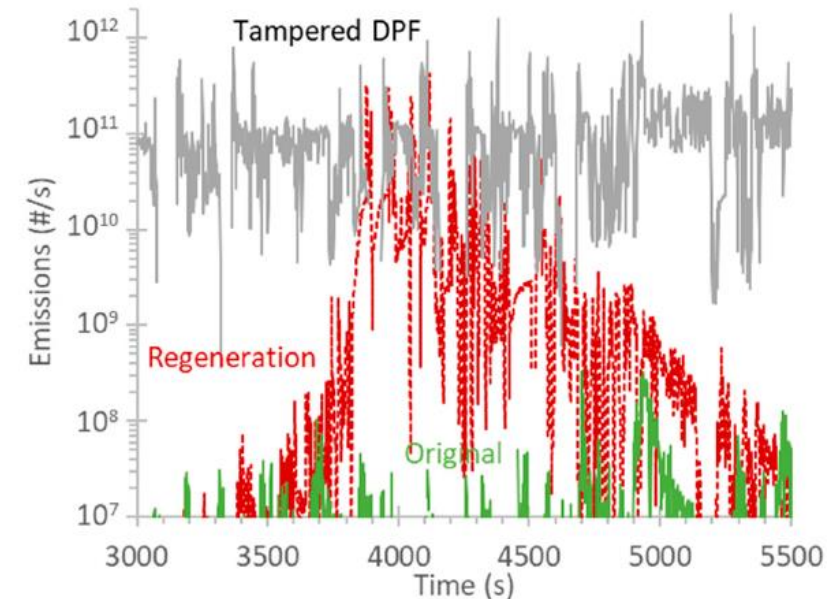
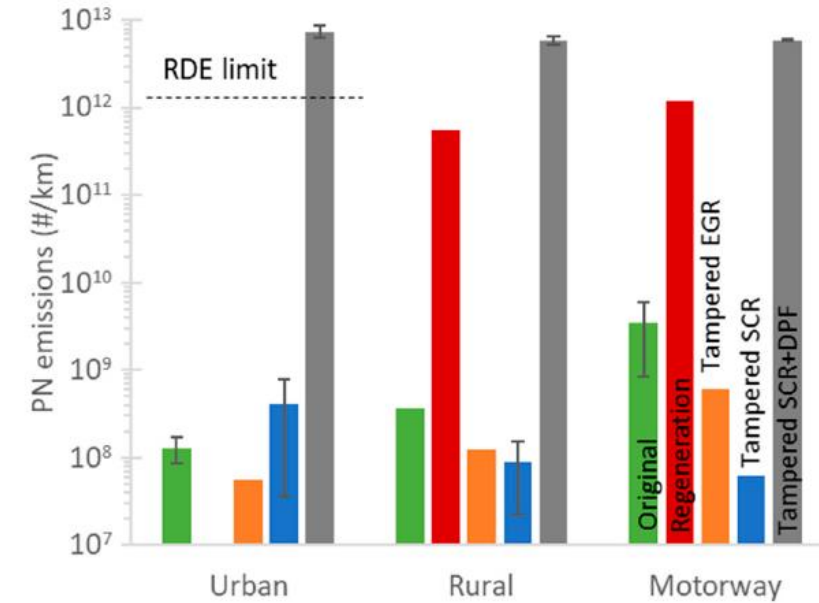
- No impact on PN

## Tampered SCR+DPF

- Exceedance of the PN limit 5-6 times

## Regeneration (original)

- PN reached the Euro 6 limit (not applicable)
- Filtration efficiency 84%



# Summary

- Tampering resulted in orders of magnitude increase of NO<sub>x</sub> emissions
- Similarly for PN

Category	Description	Target	Approach	CO <sub>2</sub>	NO <sub>x</sub>
LD (Euro 6d-Temp)	Passenger car	EGR	ECU flashing <sup>1</sup>	3–9%	1.1–1.5 g/km
		SCR (DEF)	ECU flashing	3–9%	0.9–1.2 g/km
		SCR + DPF	ECU flashing	8–15% <sup>2</sup>	1.1–1.5 g/km
LD (Euro 6b)	Passenger car	EGR + SCR	ECU flashing <sup>3</sup>	<5%	0.2–0.9 g/km
HD (Euro VI D)	N2 truck	SCR (DEF)	DEF emulator	no impact	1.0–1.7 g/kWh
HD (Euro VI C)	N3 truck	NO <sub>x</sub> sensor	NO <sub>x</sub> emulator	2–11%	No impact <sup>4</sup>
		SCR + DPF	SCR emulator x3	2–11%	5–6 g/kWh
NRMM (Stage IV)	Agricultural tractor	SCR	DEF emulator	no impact	4.8 g/kWh
		Power	ECU flashing	+15% power	n/a

<sup>1</sup> The EGR tampering affected the SCR negatively and resulted in high NO<sub>x</sub> emissions; <sup>2</sup> plus 2.4–3.0% benefit from the regeneration; <sup>3</sup> the SCR tampering was probably not successful and resulted in relatively low increases of NO<sub>x</sub>; <sup>4</sup> ammonia slip was measured. DEF = Diesel exhaust fluid; DPF = Diesel particulate filter; ECU = electronic control unit; EGR = exhaust gas recirculation; HD = heavy duty; LD = light duty; NRMM = non-road mobile machinery; SCR = selective catalytic reduction.



# Tampering motives

Translating CO<sub>2</sub> reductions in fuel savings from tampering resulted in:

- 30-100 Euros per year from EGR or DEF deactivation. For trucks the values could be up to 10 times higher. The cost of tampering EGR or DEF (SCR) was around 300-600 Euros
- 100-180 Euros per year from DPF removal. For trucks the values could be up to 10 times higher. The cost of DPF removal was around >1500 Euros.

For light-duty vehicles tampering is likely to appear in:

- vehicles requiring repair or replacement of exhaust aftertreatment components, thus already some years in the market, or in
- professional or commercial vehicles performing a significant number of kilometres annually

For heavy-duty vehicles DEF and fuel savings could be a motive even early in the vehicles' life

# Tampering motives

- The regulatory framework is not so strict
- Finding a workshop willing to tamper the vehicle is not uncommon
- There are many sites and forums available if one wants to install the tampering device independently
- There are **no robust procedures to detect tampering**: the periodical technical inspection (typically every two years after four years from the purchase) does not include NOx testing or PN

# EU legislative framework: Roadworthiness package



## Directive 2014/45/EU

Periodic roadworthiness tests for motor vehicles and their trailers  
(*"PTI Directive"*)



## Directive 2014/46/EU

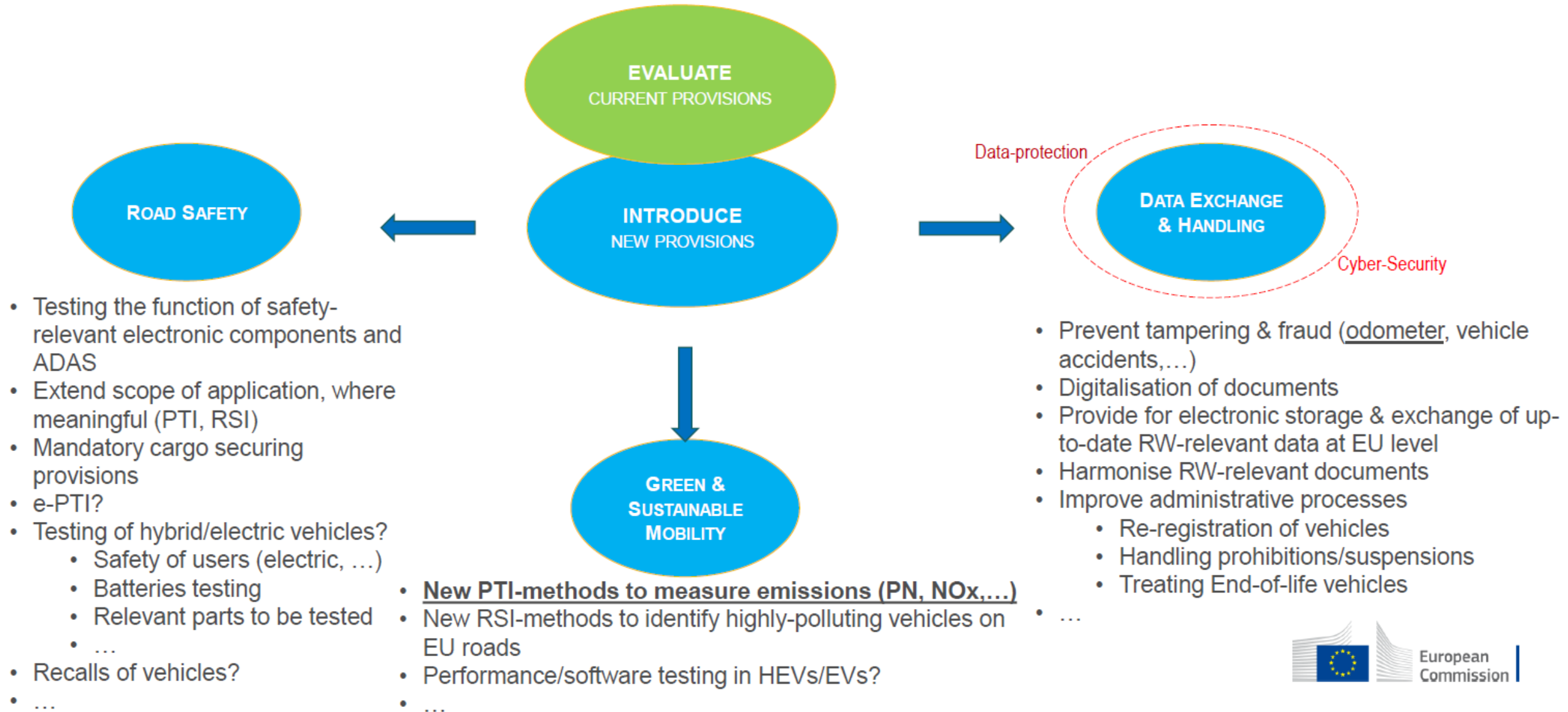
amending Directive 1999/37/EC  
Registration documents of vehicles



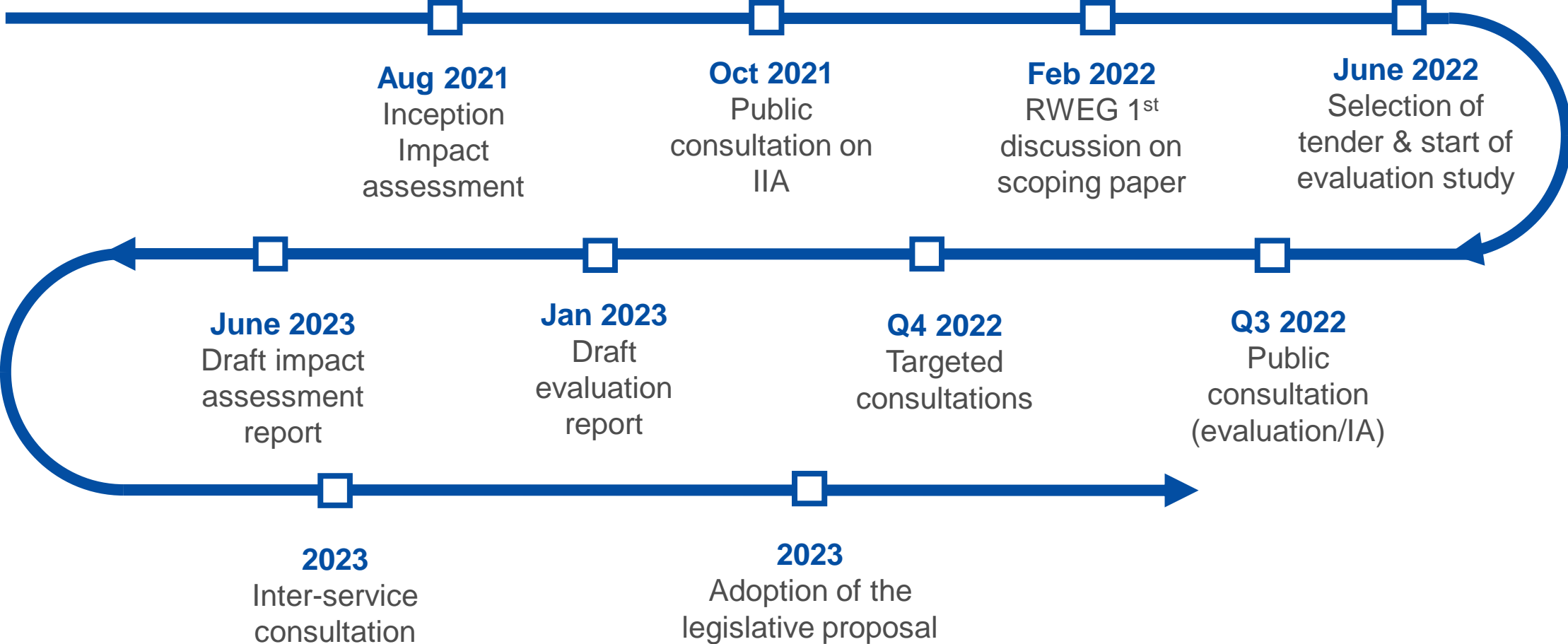
## Directive 2014/47/EU

Technical roadside inspection of the roadworthiness of commercial vehicles circulating in the EU  
(*"RSI Directive"*)

# Revision of the roadworthiness package



# Time planning





# Emission measurements

- Measurement of PN emissions

- Notifications under Directive (EU) 2015/1535 received from NL, DE
- Introduction of PN tests at PTI from July 2022 (BE), Jan 2023 (NL), Jan or July 2023 (DE)
- Introduction of PN tests at PTI from Jan 2023 (CH)
- Commission guidance on PN is planned by end of 2022
- Focus on Diesel vehicles with DPF

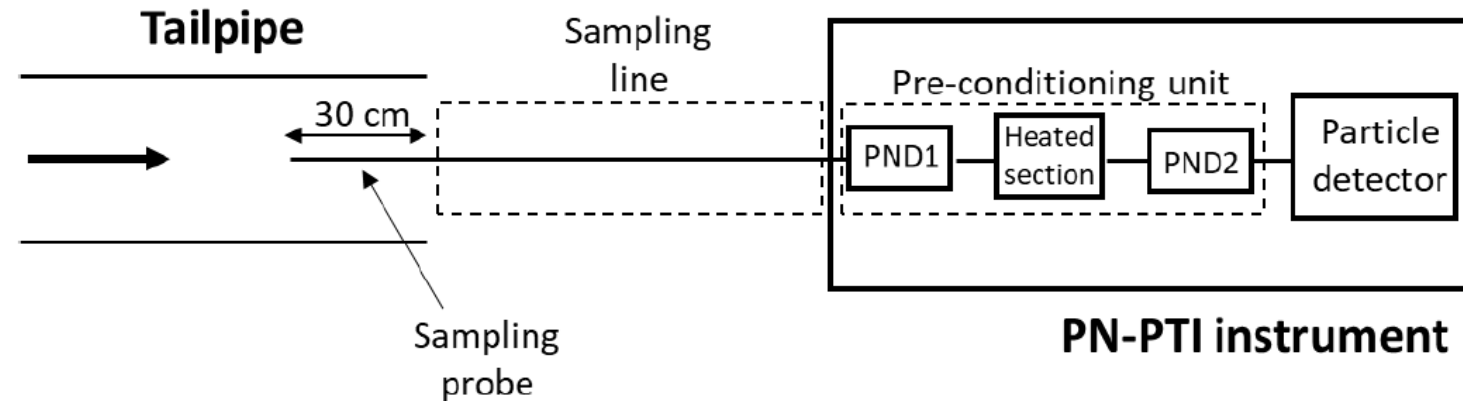
- Measurement of NOx emissions

- Large variety of after-treatment system principles
- Various approaches (with different focus)
- Focus on Diesel vehicles with SCR



# Guidance for PN measurements at PTI

- Work by JRC and DG-MOVE in consultation with the Roadworthiness Expert Group (Member States and industry representatives)
- Scope:
  - Gasoline vehicles are out of the scope at this stage due to lack of experimental data to support a robust measurement procedure
  - Application of the method to vehicles that during type approval did not have a solid PN limit, might be too strict for vehicle owners with DPF
- Technical requirements:
  - Based on current PTI procedures
- Limit:
  - Applicable to any limit
  - with focus 250 – 1000k #/cm<sup>3</sup>



With dash lines the optional parts

Thank you