

# Advanced inspection and maintenance (I/M) methods to identify high emitters

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32<sup>nd</sup> CRC Real World Emissions Workshop





# Outline

- Introduction to Periodic Technical Inspection (PTI)
- About the PTI Test Pilot
- Investigation of metrics for NO<sub>x</sub> quantification
- Comparisons of Enhanced PTI results against the Euro Standards and Type Approval results
- Conclusions





# Periodic Technical Inspection (PTI) Today

- The European Union methods of inspection and maintenance, Periodic Technical Inspection (PTI) for exhaust emissions are mostly regulated by Directive 2014/45/EU:
  - Correct performance of complex exhaust after-treatment systems are verified only by visual inspection
  - Requires different emission tests based on vehicle engine type:
    - Positive ignition engine emissions use a certified exhaust gas analyzer to determine:
      - Gaseous emissions (CO, CO<sub>2</sub>, O<sub>2</sub>, HC) do not exceed OEM/vehicle type specified thresholds,
      - Lambda coefficient not outside OEM specified range, or if not specified not outside  $1 \pm 0.03$ ,
      - OBD read-out does not indicate significant malfunction.
    - Compression ignition engine emissions use certified opacity meter and protocol to determine:
      - Opacity does not exceed OEM/vehicle type specified thresholds.
- Directive 2014/45/EU is out of date:
  - No check for relevant pollutants such as NO<sub>x</sub> and PN,
  - There are concerns around the sensitivity of the smoke opacity method to detect particulate emission issues from vehicles fitted with particulate filters.





- Post Dieselgate, European emission measurement is progressing:
  - EU has implemented PMP and RDE protocol for vehicle type-approval testing, with measurement of CO, NO<sub>x</sub>, HC+NO<sub>x</sub>, PM and, from Euro-5, measurement of PN
  - Some member states are introducing new PTI regulations independently of EU regulation:
    - Netherlands, Germany and Belgium for PN for diesel vehicles post Euro-5
    - The CITA NO<sub>x</sub> Taskforce are working toward the addition of NO<sub>x</sub> measurement to PTI procedures
  - EU regulates OBM CO<sub>2</sub> monitoring for new vehicles from 2021, with PTI procedures to be defined
- But there is much progress yet to be made:
  - Particulate protocol, measurement & threshold to be tested
  - NO<sub>x</sub> protocol, measurement & threshold to be developed and tested
  - CO and CO<sub>2</sub> protocol, measurement & threshold to be developed and tested
  - Advocating EU homogeneity and building future-proof systems
- Existing PTI equipment cannot meet the new requirements.



# PTI Test Pilot Data – Introduction



# Aims and Objectives of the PTI Pilot Test Campaign

- PTI format:

**Minimize  
Test Time**

Set Vehicle  
Conditioning

Check  
Repeatability

**NO<sub>x</sub>  
Protocols**

- Pollutant trends:

**Euro  
Standards**

**Type  
Approval\***

Vehicle Conditioning and repeatability objectives will not be addressed in this presentation.

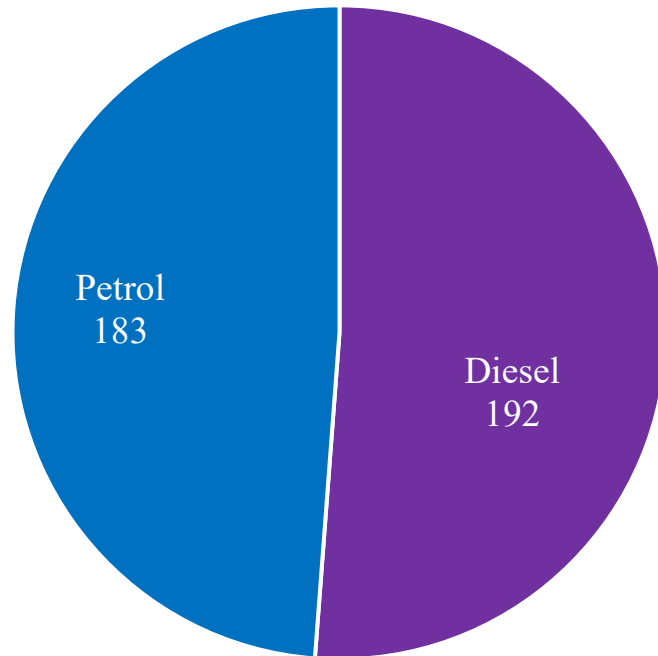
\*Comparison on PTI results against vehicle type approval results was attempted but not achieved (explained later)



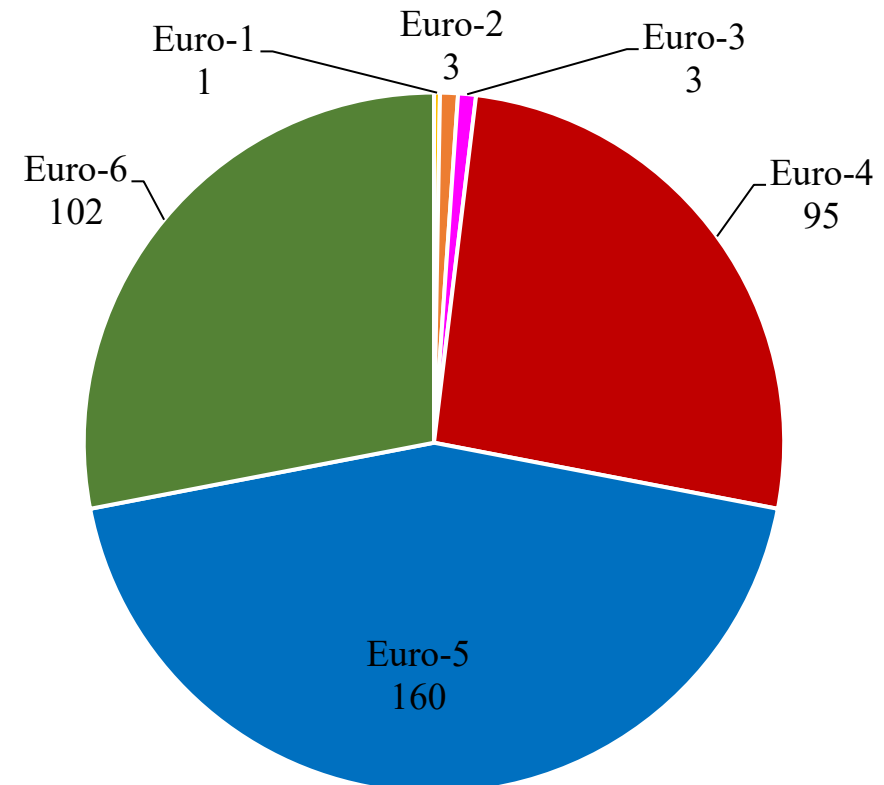
# Fleet Composition – Vehicle Information

- The results presented are part of an **ongoing** trial at Opus, Sweden
- At time of data processing, **375 vehicles** had been tested (total now above 450 vehicles, and counting)

### Fuel Type of Vehicles



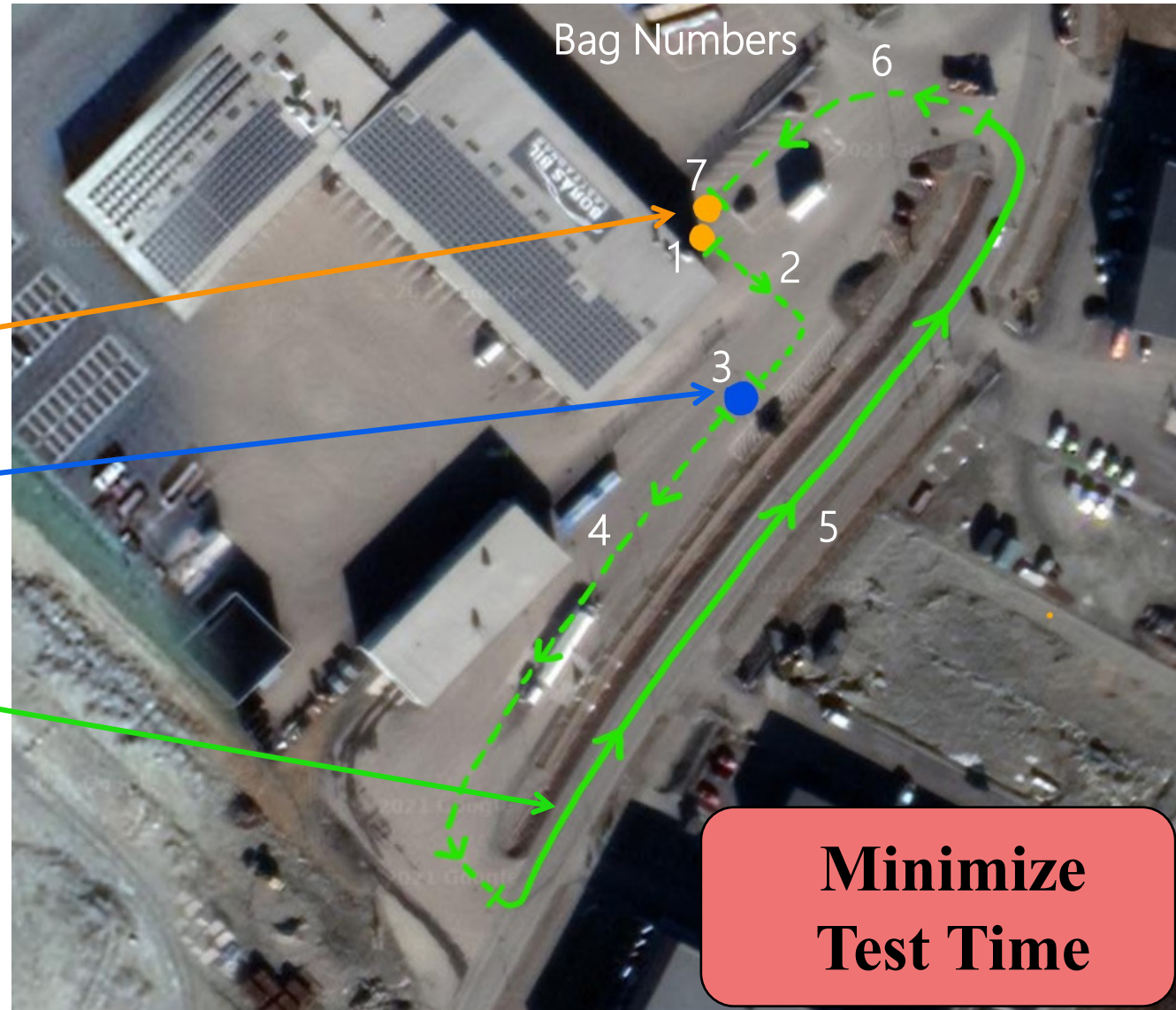
### Emissions Standards of Tested Vehicles





# Final Test Protocol– Extra 5 Minutes onto PTI

Bag No.	parSYNC Location	Description
0	Bench	Sample clean air while parSYNC is on the bench.
Zeroing	Bench	Zero the parSYNC. Idle the vehicle.
0	Vehicle	Move parSYNC to vehicle. Sample exhaust gas for ~10 seconds.
1	Vehicle	PN protocol – 60 seconds of idle – conducted while car is at garage
2	Vehicle	Drive to emissions shed
3	Vehicle	NOx High Idle – Follow standard PTI protocol for gasoline and diesel vehicles
4	Vehicle	Drive to NOx Acceleration test start point
5	Vehicle	NOx Acceleration – <i>Idle for 10 seconds</i> , then accelerate quickly to 30 kph, then brake normally (not hard) to a complete stop, <i>idle for 10 seconds</i>
6	Vehicle	Drive back to garage.
7	Vehicle	PN protocol – 60 seconds of idle
8	Bench	Disconnect parSYNC. Sample clean air for at least 60 seconds.
Zeroing	Bench	Zero the parSYNC.







# Device used - The parSYNC iPEMS

## ➤ Lightweight & Easy To Use

- Total System Weight: 6.7 kg (22.1 lb)
  - parSYNC<sup>®</sup> Weight: 4.1 kg (13.7 lb)
  - CUBE<sup>™</sup> Weight (with one battery): 2.6 kg (8.4 lb)

## ➤ Battery Life

- 4-5 hours typically

## ➤ GasMOD<sup>™</sup> Sensor Cartridge

- Electrochemical: NO (0-5000ppm) & NO<sub>2</sub> (0-300ppm)
- NDIR: CO<sub>2</sub> (0-20%), CO (0-15%)

## ➤ Particulates Sensor Cartridge

- PN/PM (10 to 10,000nm = 0.01 to 10µm)



# The new parSYNC **FLEX** iPEMS

Gases – CO, CO<sub>2</sub>, NO, NO<sub>2</sub> + **HC and O<sub>2</sub>**

Particulates - Ionization,  
Scattering, and Opacity,  
**with advanced  
temperature control**

**Enhanced chiller and  
volatile particle removal**

**Hot-swap Milwaukee Li-Ion  
batteries for full-day of  
testing**

**Onboard display and data  
storage + WiFi Access-point**

**Full CAN + support for  
external sensors**



**Integrated GPS and Ambient  
Pressure, Temperature,  
Humidity**

**Integrated wireless OBD  
reader for LD and HD**

*... and still light-weight  
(10 kg) and installs in  
minutes*





# PTI Pilot Data – Comparisons Between Metrics for NO<sub>x</sub> Quantification

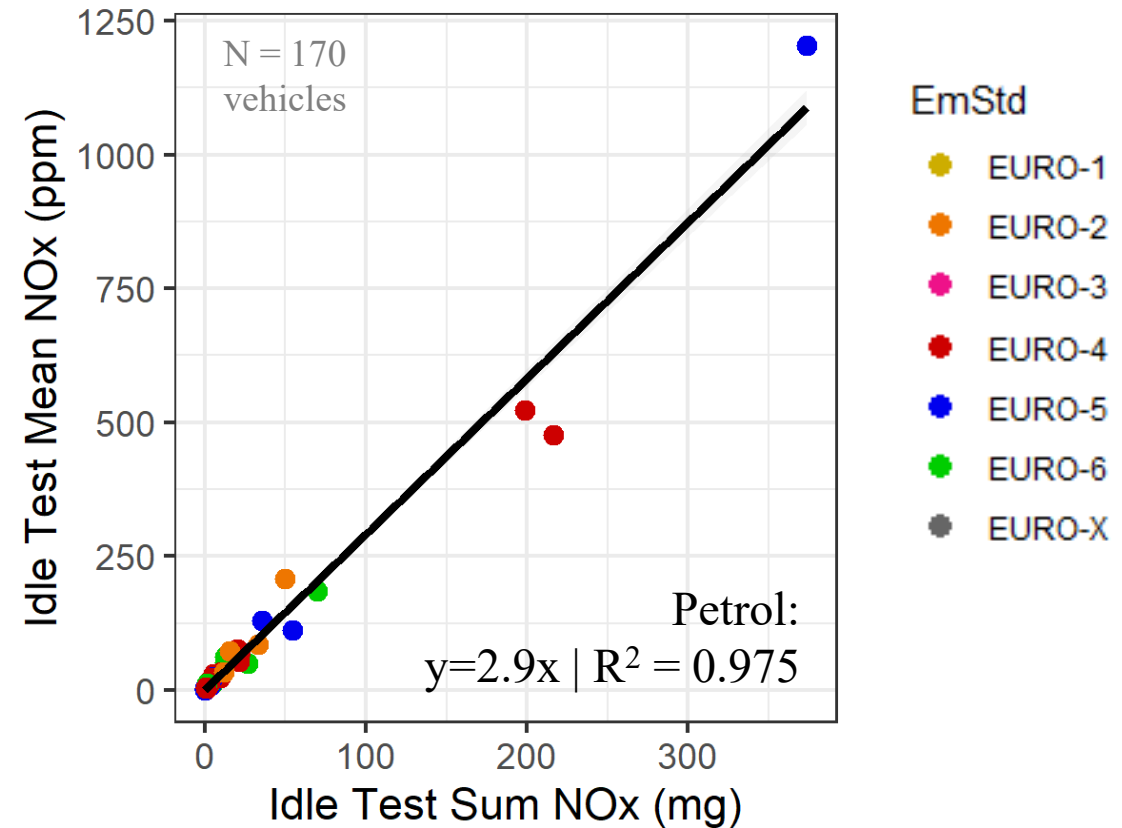
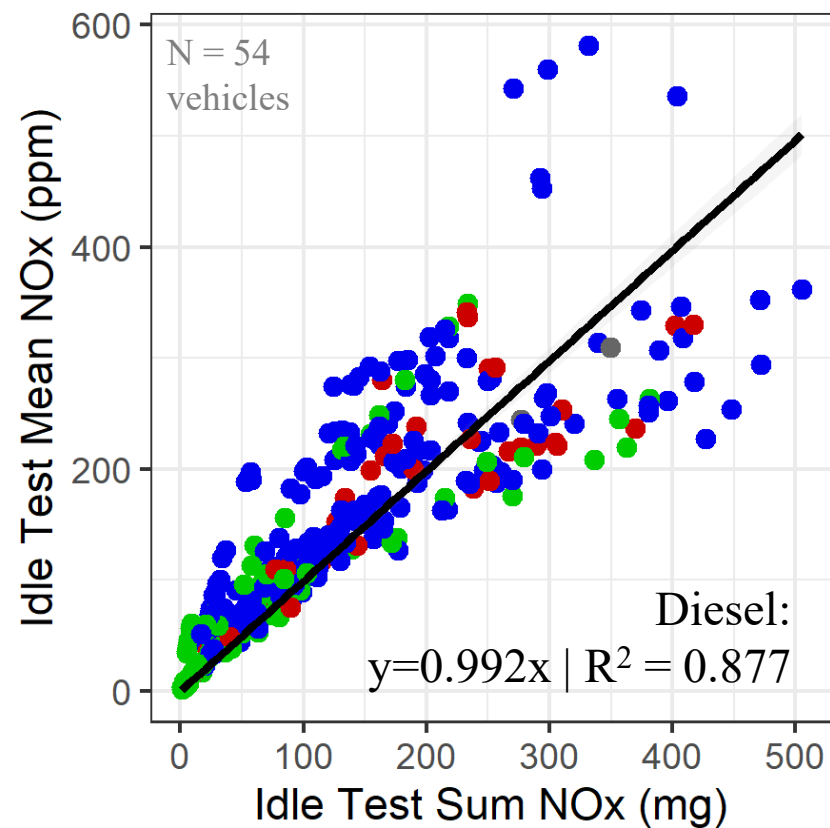
**NO<sub>x</sub>  
Protocols**





# NO<sub>x</sub> concentration and mass emissions on NO<sub>x</sub> Idle Tests

For simplicity, PTI needs to use concentration values rather than mass emissions. Is this simplification still effective enough to capture high emitters? According to these results, *yes*.

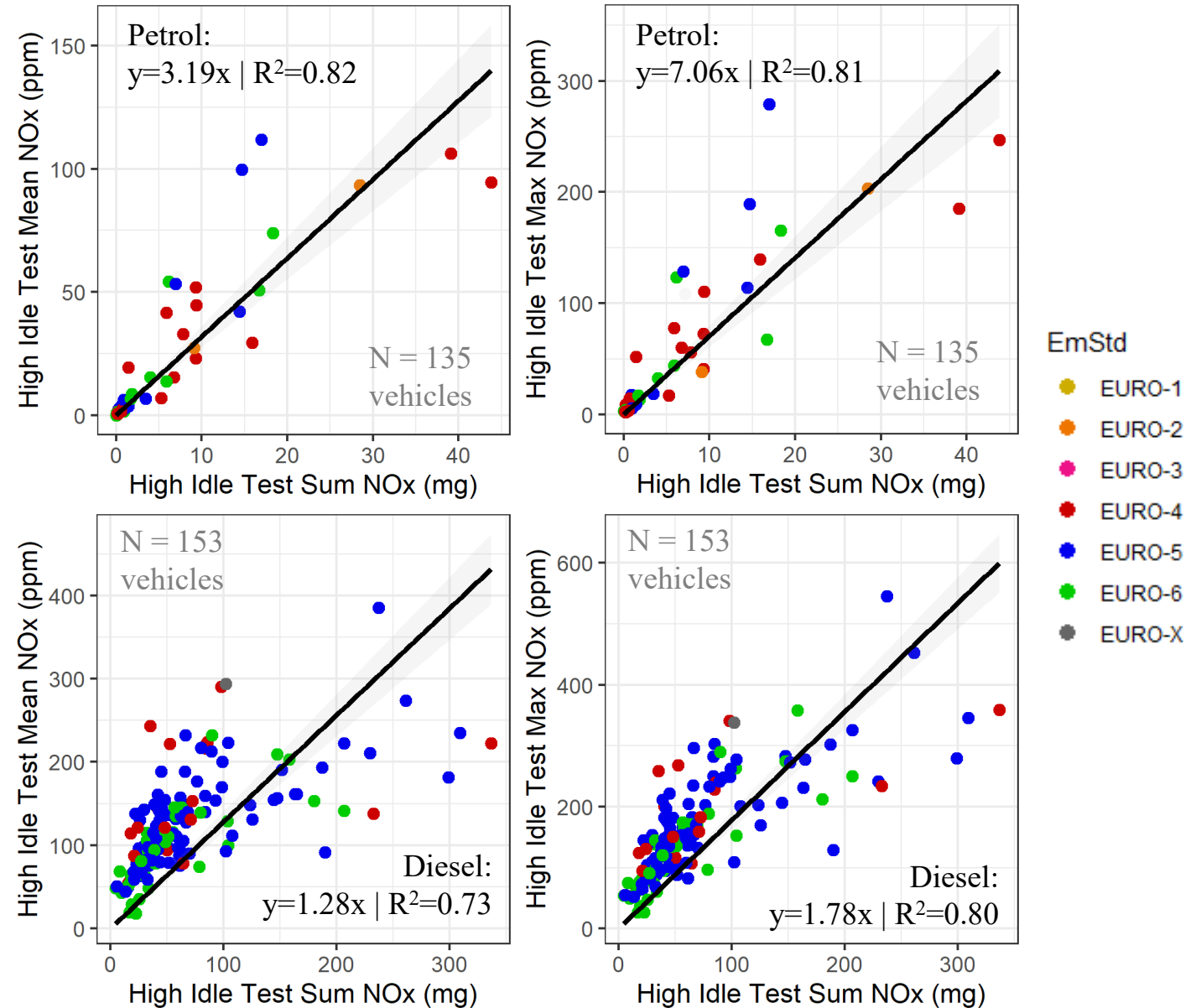




# NO<sub>x</sub> concentration vs. mass emissions on NO<sub>x</sub> High Idle Tests

NO<sub>x</sub> concentration is an effective metric for capturing high emitters on a high idle protocol too.

Both mean and maximum concentration values give similar strength correlations with mass emissions (max slightly stronger).

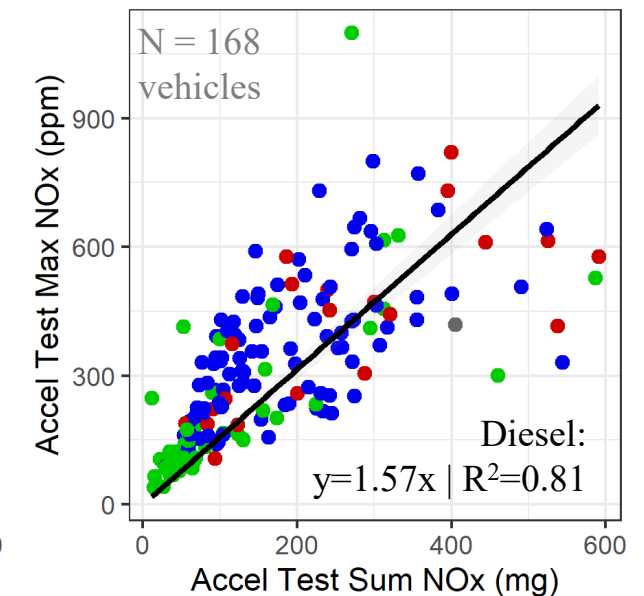
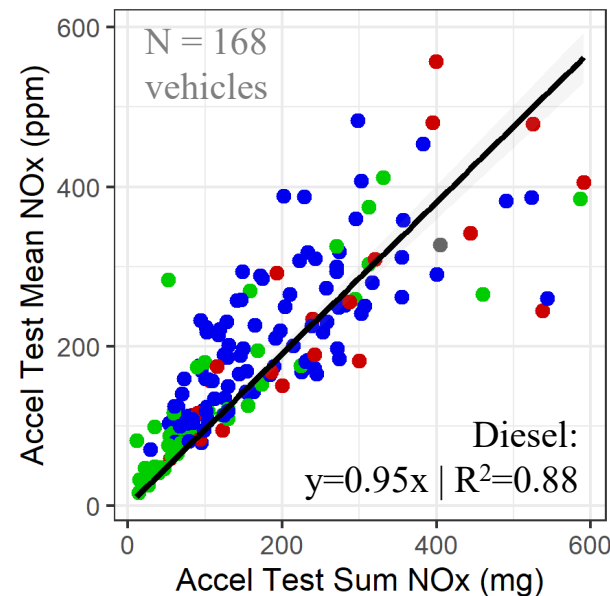
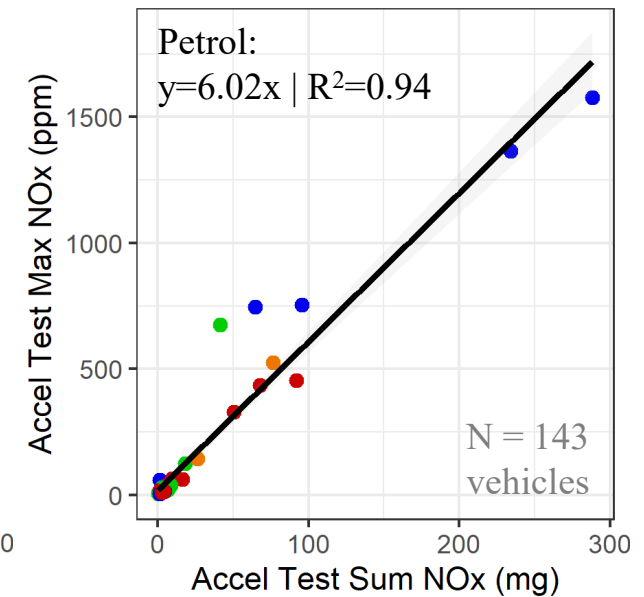
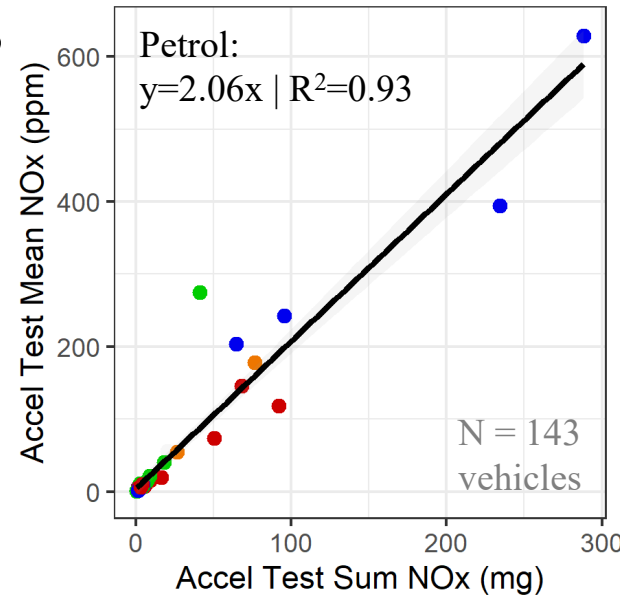




# NO<sub>x</sub> concentration vs. mass emissions on NO<sub>x</sub> Acceleration Tests

NO<sub>x</sub> concentration is an effective metric for capturing high emitters on a dynamic acceleration protocol too.

The mean concentration gives a stronger correlation than max concentration to mass emissions, but relies on OBD data for isolation of the appropriate test section.







# Comparing correlations between NO<sub>x</sub> concentration and mass emissions on High Idle and Accel Tests

The results in this section demonstrate that NO<sub>x</sub> concentration can be used effectively to quantify NO<sub>x</sub> emissions

	Mean Values	Max Values
<b>Idle Test</b>	$y=1.04x \mid R^2=0.83$	Not Applicable
<b>High Idle Test</b>	$y=1.29x \mid R^2=0.72$	$y=1.81x \mid R^2=0.77$
<b>Acceleration Test</b>	$y=0.976x \mid R^2=0.86$	$y=1.67x \mid R^2=0.73$

- Idle test should use mean concentration as the metric.
- High idle test can use either mean or maximum concentration.
- Acceleration test mean values have slightly stronger correlation to the mass emissions than the maximum values. However, the mean would require OBD data for proper isolation of the test section (same for high idle).



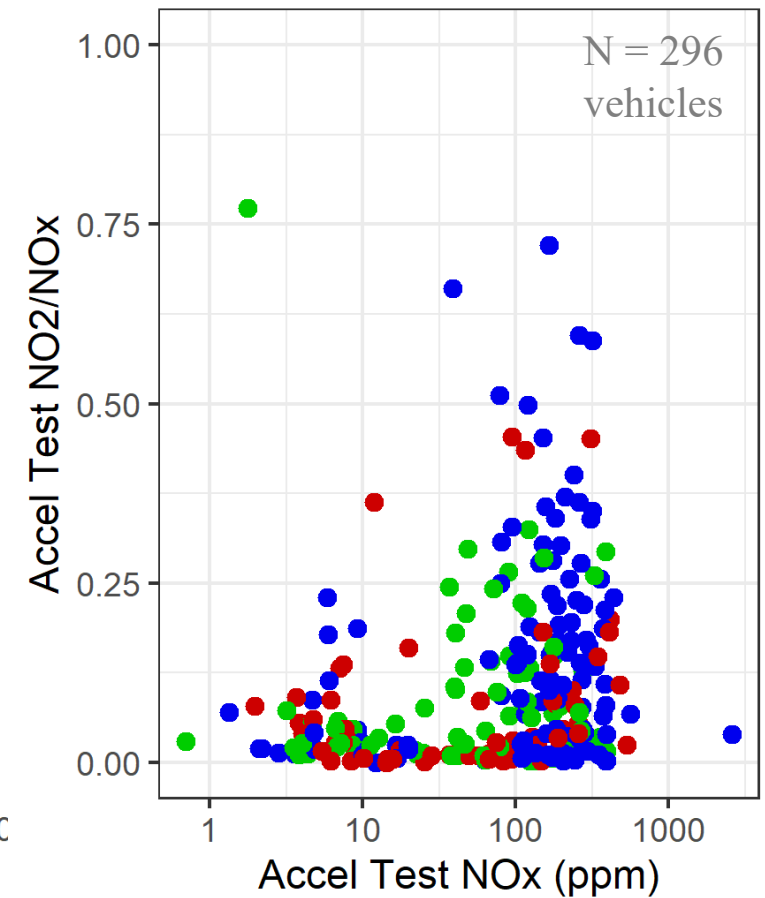
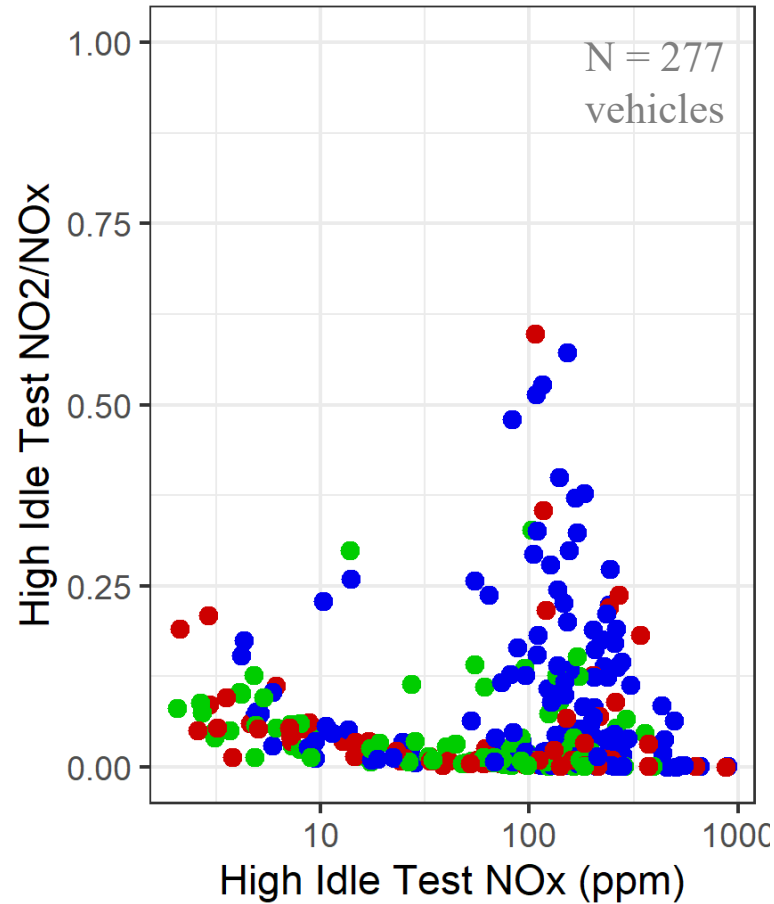
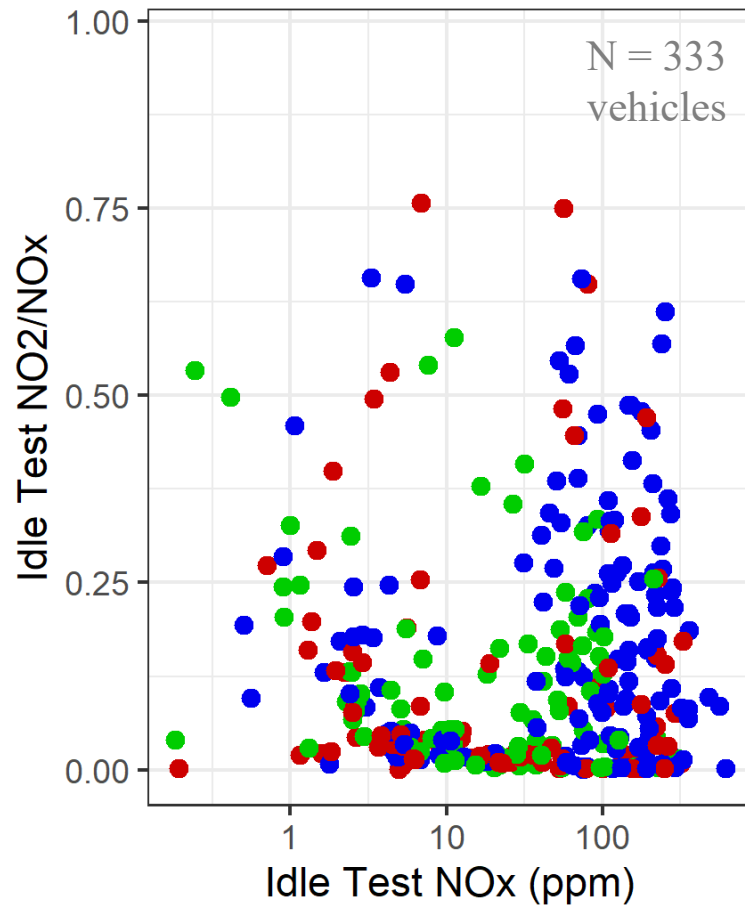


# Investigating the contribution of NO<sub>2</sub> to NO<sub>x</sub>

Many vehicles have a non-trivial NO<sub>2</sub> concentration

EmStd

- EURO-4
- EURO-5
- EURO-6







# PTI Pilot Data – Comparisons of Enhanced PTI Results against the Euro Standards

**Euro  
Standards**

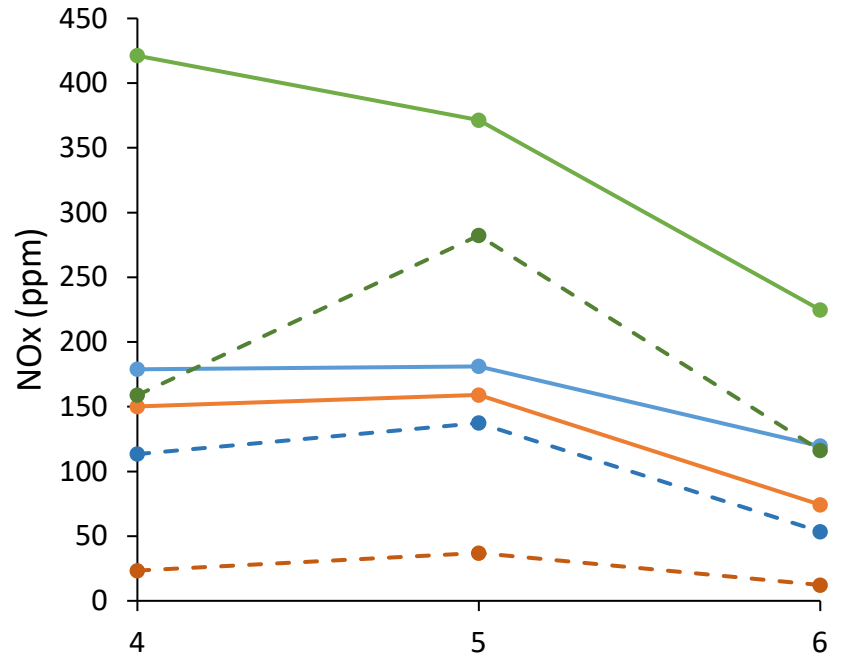
**Type  
Approval**





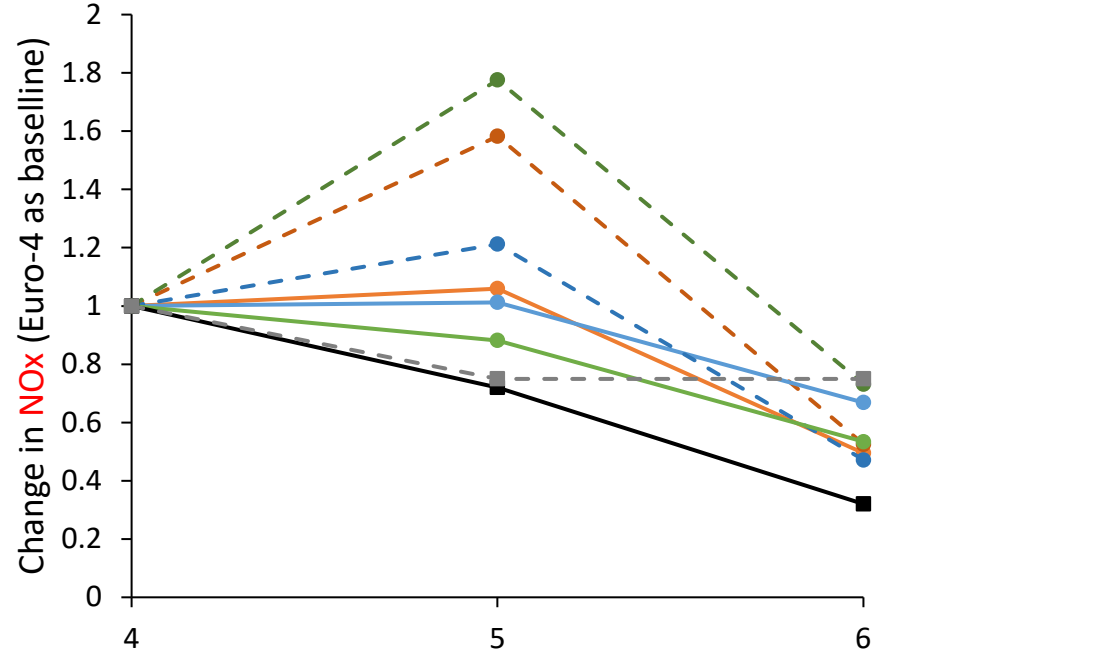
# Do vehicles meet the expectations of the Euro standards?

The real-world PTI NOx emissions for vehicles generally increased compared to the type approval limits from Euro-4 to Euro-5, but then decreased to Euro-6 – the changes post-Dieselgate are working



Legend for NOx (ppm) graph:

- Diesel\_Idle (#/cm3)
- - -●- - - Petrol\_Idle (#/cm3)
- Diesel\_HighIdle (#/cm3)
- - -●- - - Petrol\_HighIdle (#/cm3)
- Diesel\_Accel (#/cm3)
- - -●- - - Petrol\_Accel (#/cm3)



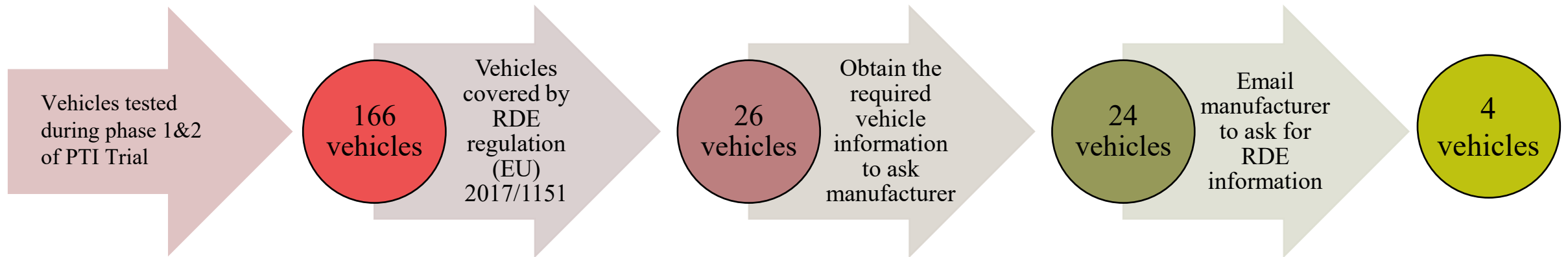
Legend for Change in NOx (Euro-4 as baseline) graph:

- Diesel\_Idle (#/cm3)
- - -●- - - Petrol\_Idle (#/cm3)
- Diesel\_HighIdle (#/cm3)
- - -●- - - Petrol\_HighIdle (#/cm3)
- Diesel\_Accel (#/cm3)
- - -●- - - Petrol\_Accel (#/cm3)
- Diesel\_Standard
- - -■- - - Petrol\_Standard



# Comparison of Enhanced PTI results against Euro-6 RDE Results

Efforts were made to compare the results from this PTI test trial to legislative RDE data for applicable vehicles. Euro-6 legislation states RDE results must be made available. However, due to low numbers of applicable vehicles and poor response rate from manufacturers, the sample is too small to draw statistically reliable comparisons.





# Conclusions

- With use of an iPEMS and optimized protocol, enhanced PTI testing adds only 5 minutes to current PTI test times
- NO<sub>x</sub> concentration *can* be used instead of mass emissions to catch high emitters on a PTI schedule
- NO<sub>2</sub> measurement should be included.
- We can see increased fleet-average NO<sub>x</sub> emissions on Euro-5 vehicles (Dieselgate), followed by a decrease on Euro-6 vehicles.
- RDE test results are difficult to obtain from manufacturers... more transparency should be required of manufacturers in future EU legislation



# Thank you for listening

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## Further Info

For full 1Hz traces of the tested vehicles:

PTI Pilot Parts 1 and 2: <https://3datx.com/ptipilot/>

Part 3 (in-progress) will be available at <https://3datx.com/request-reports/>

