

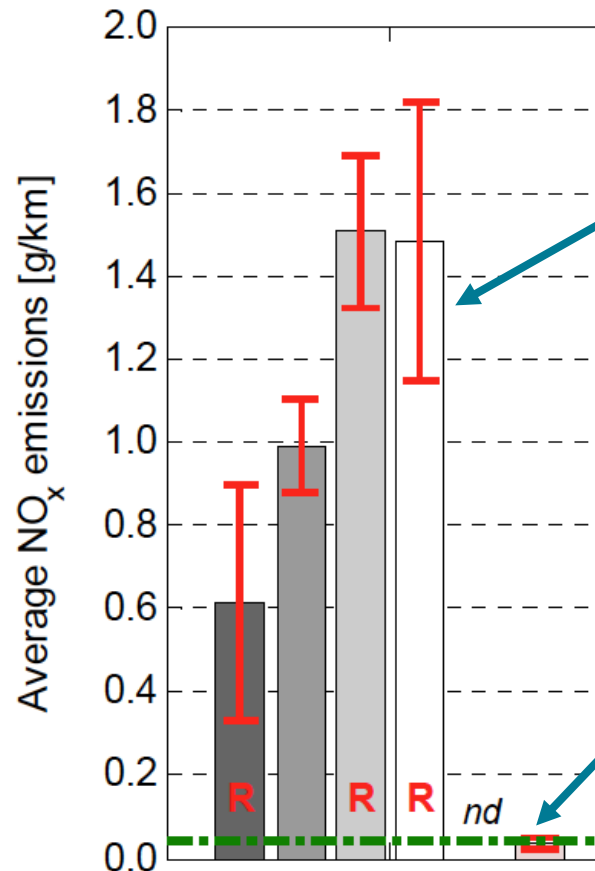
Post-Dieselgate governments' testing campaign in Europe and defeat-device screening techniques

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A comparison of laboratory vs. on-road test results for 3 diesel cars in the US triggered “Dieselgate”



On-road test



Laboratory test

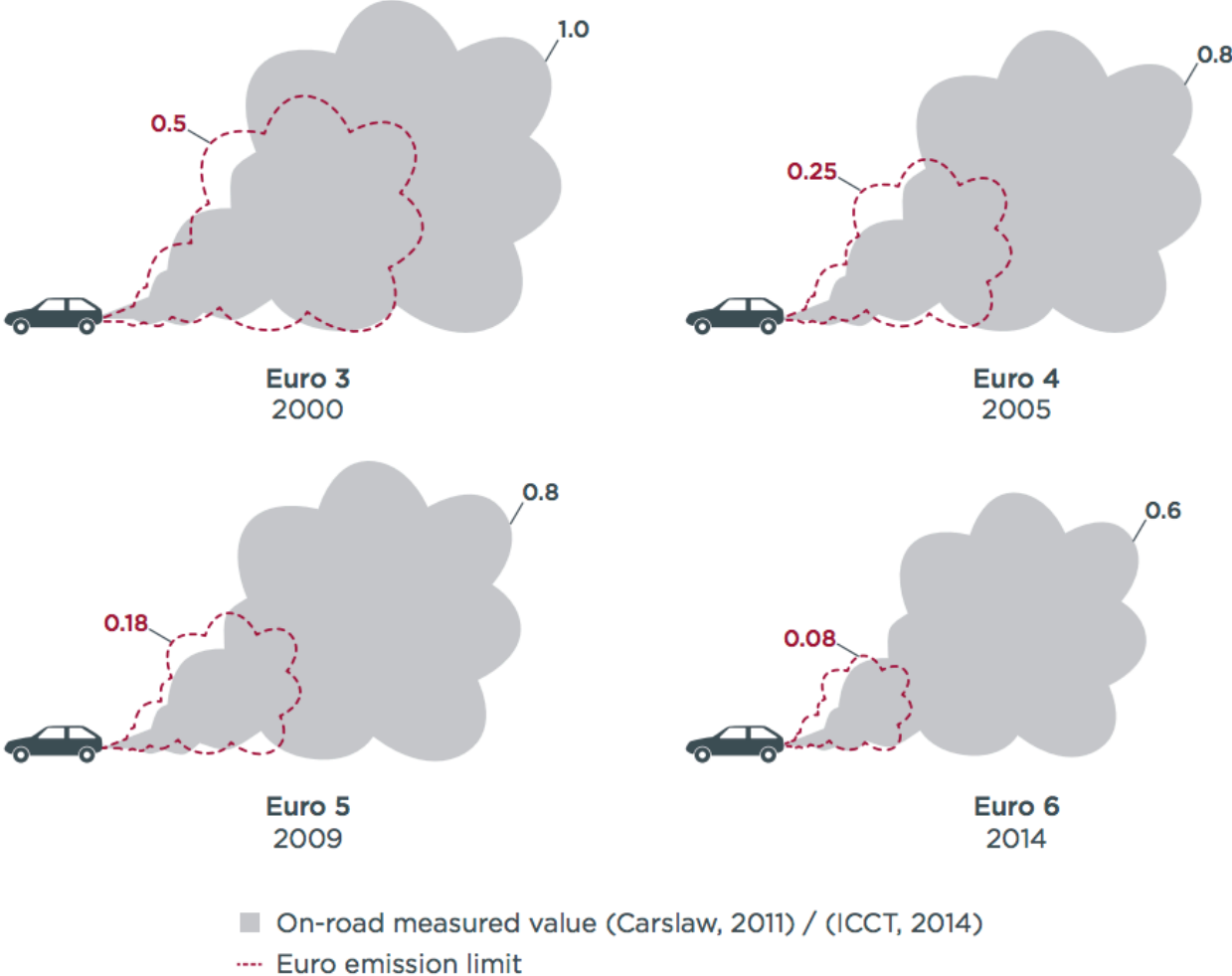


Source for photos: AVL / ERMES

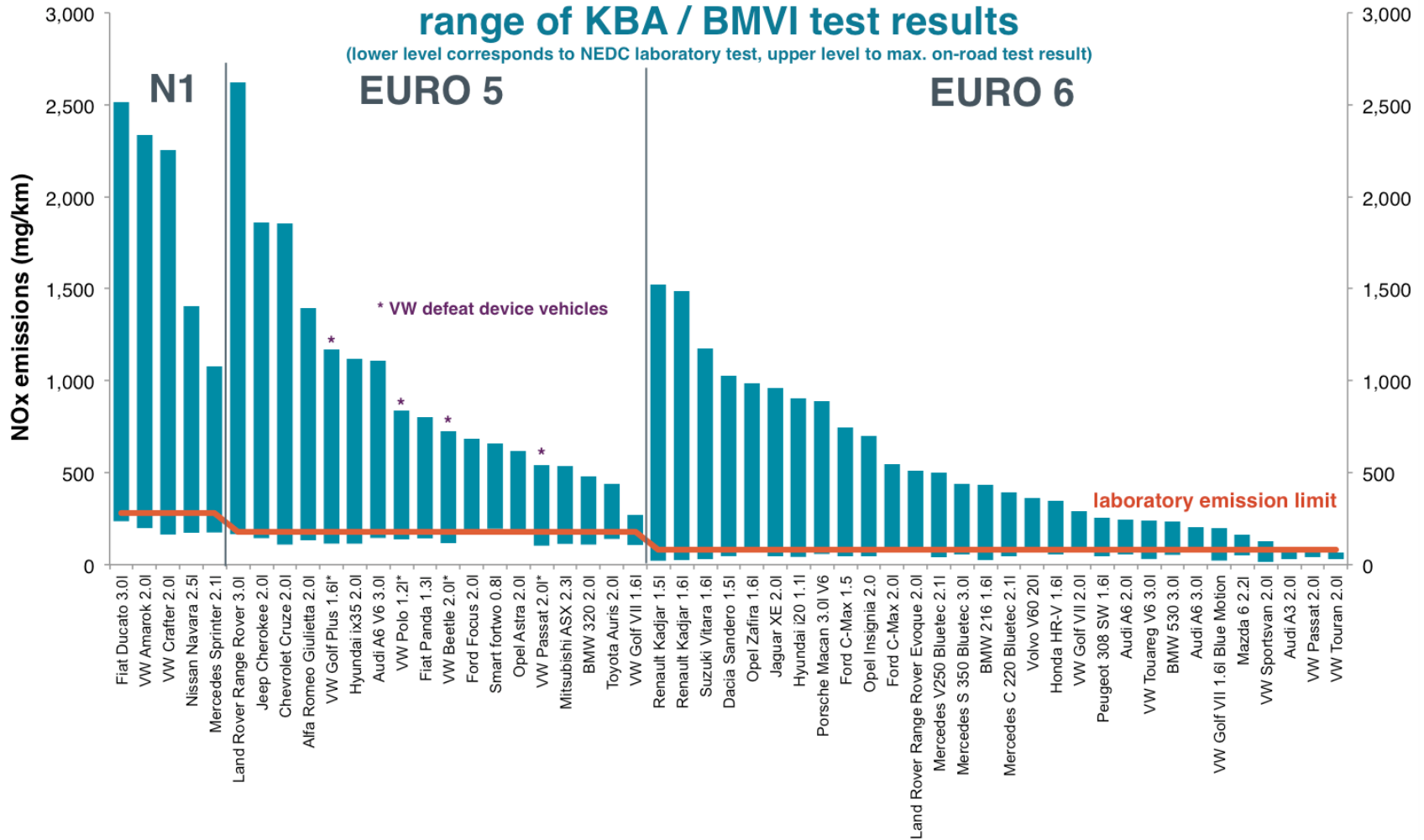
Vehicles shown on photos are not related to test results shown

Source: <http://www.theicct.org/use-emissions-testing-light-duty-diesel-vehicles-us>

In reality, nitrogen oxides emissions from diesel cars in Europe have not decreased as expected



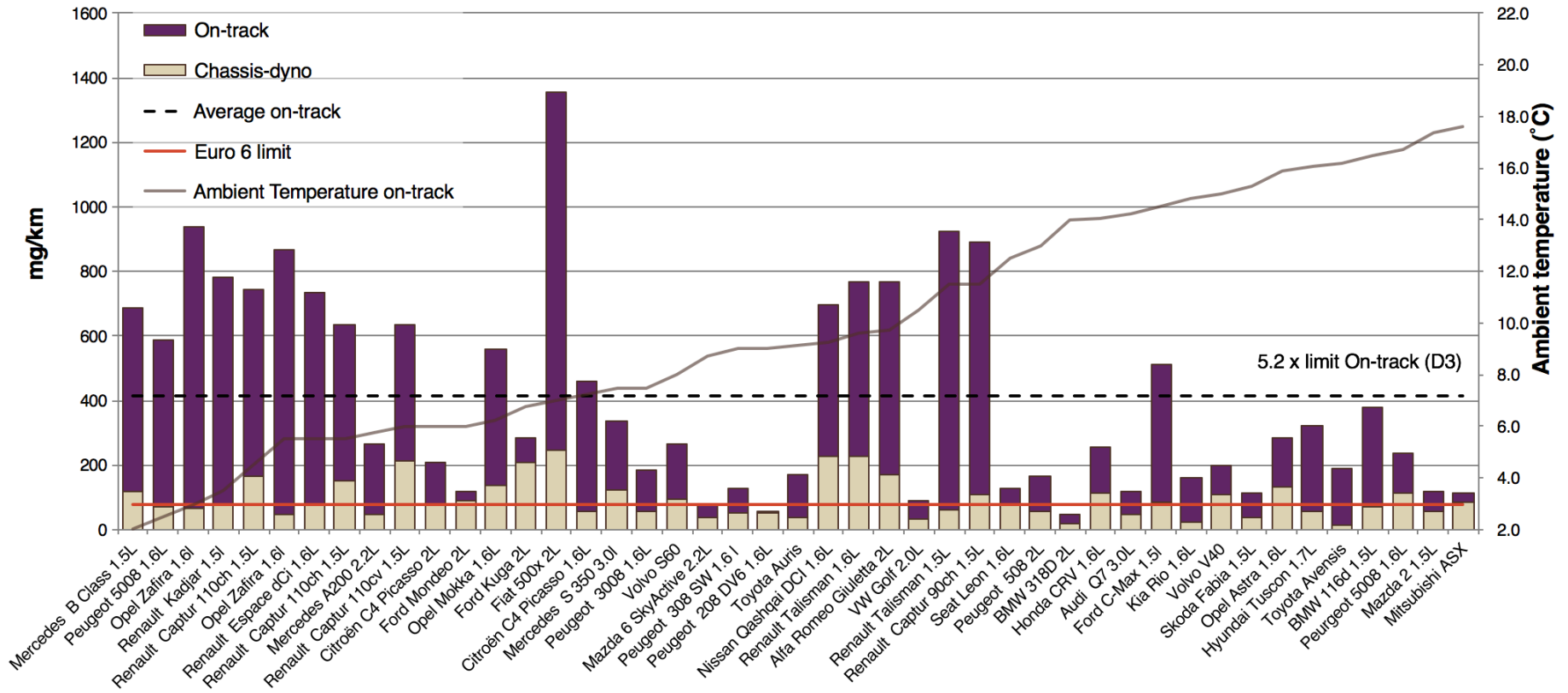
German real-world testing data found Euro 5 & 6 diesel cars emit NO_x emissions many times legal limits.



French on-track testings demonstrates that the cycle profile itself is not the only source of discrepancy

Type-approval cycle (NEDC) run on a track, and impact of ambient temperature

Euro 6 - NO_x results and limit

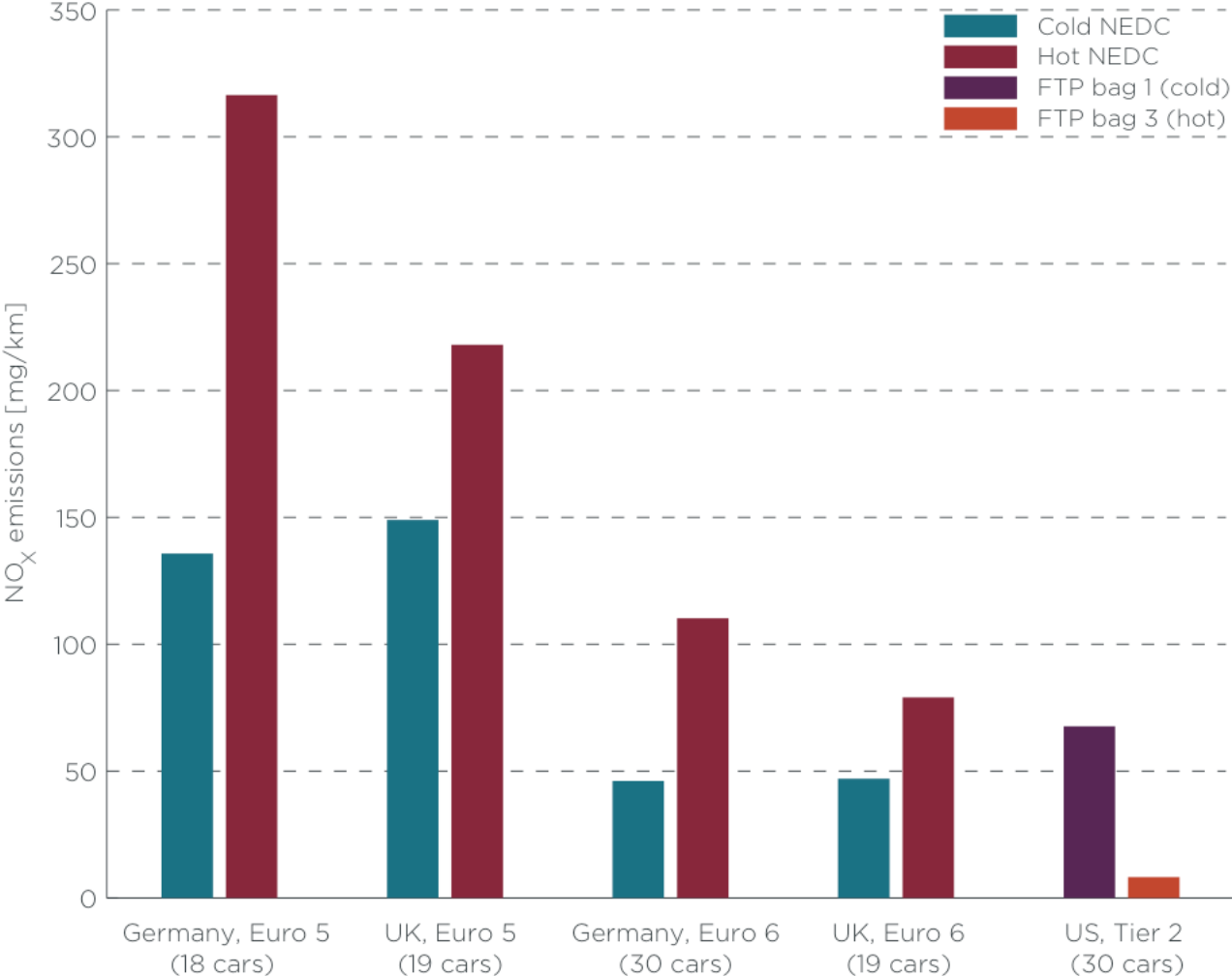


What defines defeat device ?

Strategy that:

- 1) Uses any sensing element or parameter,
- 2) to apply an auxiliary emissions strategy (AES), or auxiliary emissions control device (AECD) that leads to emissions control change,
- 3) and without a valid reason (engine protection, accidents prevention, abnormal operation, etc)
 - In the US, alternative emissions strategies need to be approved by the authorities. Their non-disclosure is a violation
 - In EU, there is no need to disclose alternative strategies (changing in September 2017). EU member's states have been reliant on manufacturers explanations, and without verifying their justifications

A popular type of defeat device in EU is recognizing cold start conditions as type approval testing



Source: <http://www.theicct.org/blogs/staff/emissions-test-defeat-device-problem-europe-not-about-vw>

Current type-approval (TA) procedure in EU

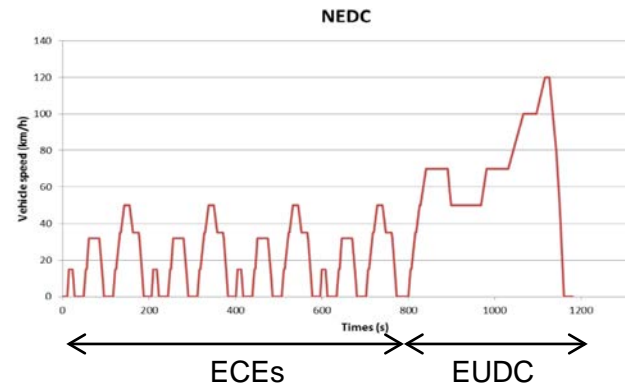
- Vehicles are approved under controlled laboratories conditions: temperature, humidity, pressure, etc



- On a well defined procedure and single cycle

+ Repeatable conditions

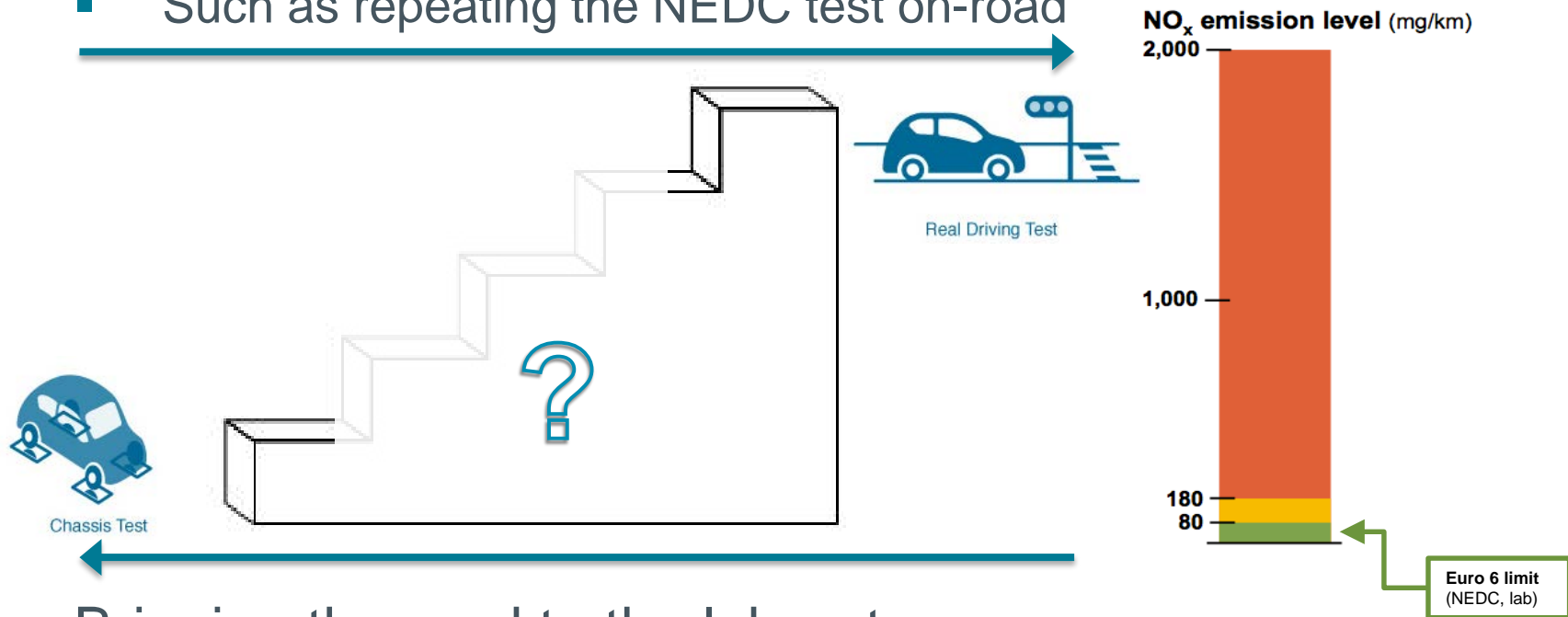
- Limited representativeness of real-world conditions
- Subject to detection and optimization



Defeat device screening: testing from road to laboratory, and laboratory to the road

- Bringing the laboratory conditions to the road

- Such as repeating the NEDC test on-road

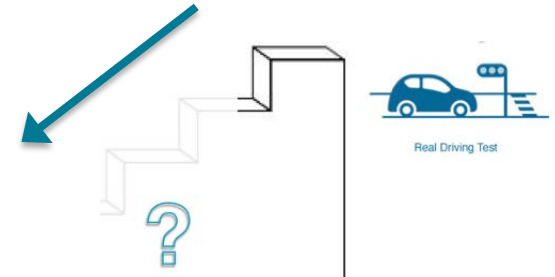


- Bringing the road to the laboratory

- Changing test conditions: lower ambient air, A/C on, etc
- Repeating a road trace on the chassis-dynamometer

Proposal of a on-road test matrix

- On-road test matrix example



Equipment on Track/Road	Test Cycle	Ambient Temperatur	Cold start	AC	OBD link
NOx sensor	Mix of urban/rural/motorway (min 3 hour of data)	-7 to 35oC	Cold and hot	Auto	Optional
PEMS or/and NOx sensor	RDE like: Mix of urban/rural/motorway (1.5 to 2 hours of data)	2-30oC	Cold (if possible)	Off	Yes (if necessary)
PEMS or/and NOx sensor	Repeated NEDC profile	20-30 deg C (if possible)	Cold (if possible)	Off	Yes (if necessary)



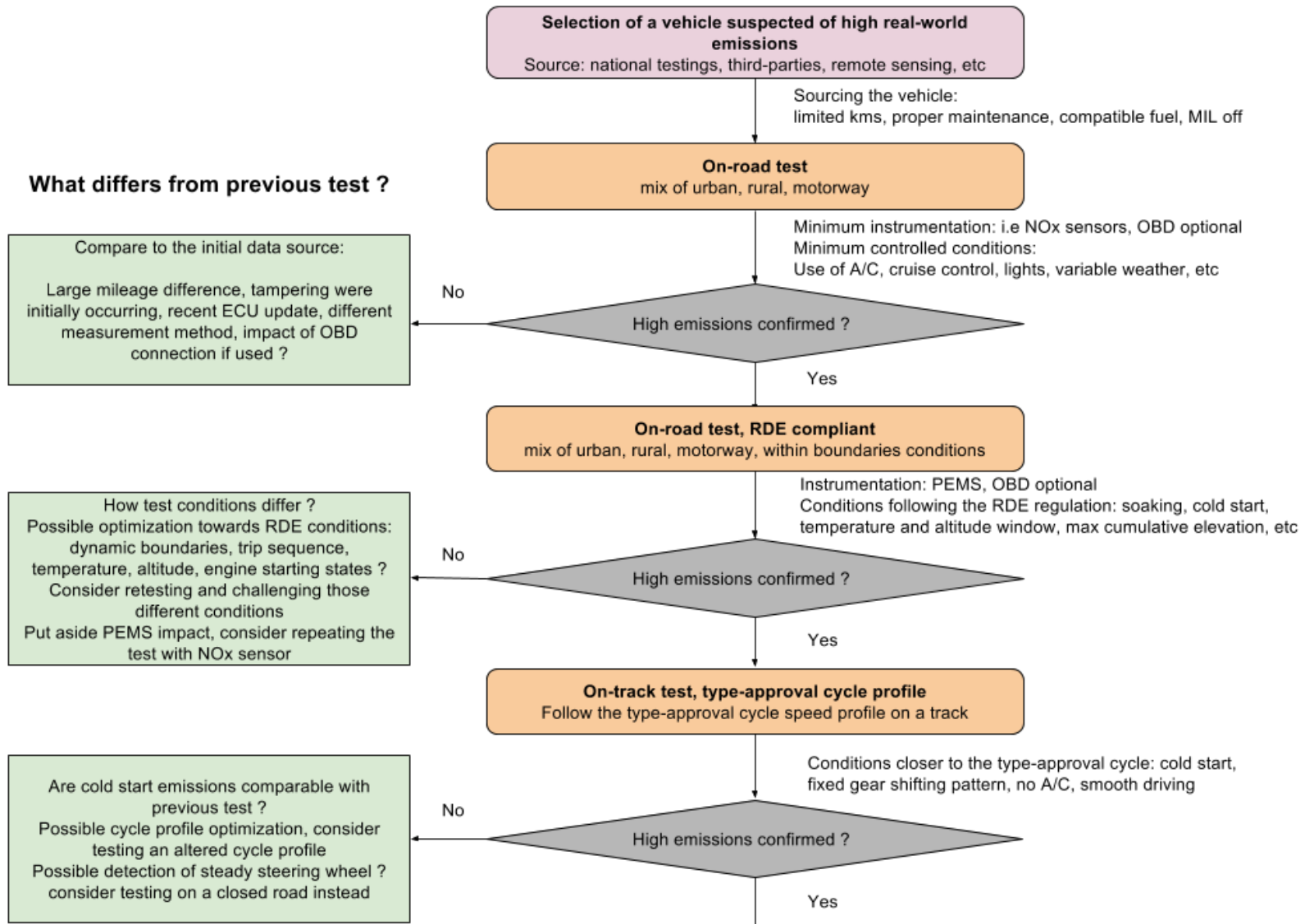
NO_x sensor



PEMS

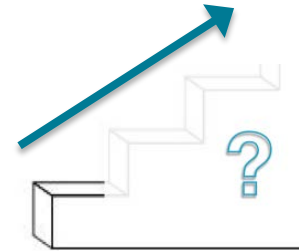
➔ Testing from real world (on-road) conditions towards closer type-approval conditions (on-track)

On-road testing guidelines



Proposal of a chassis-dynamometer test matrix

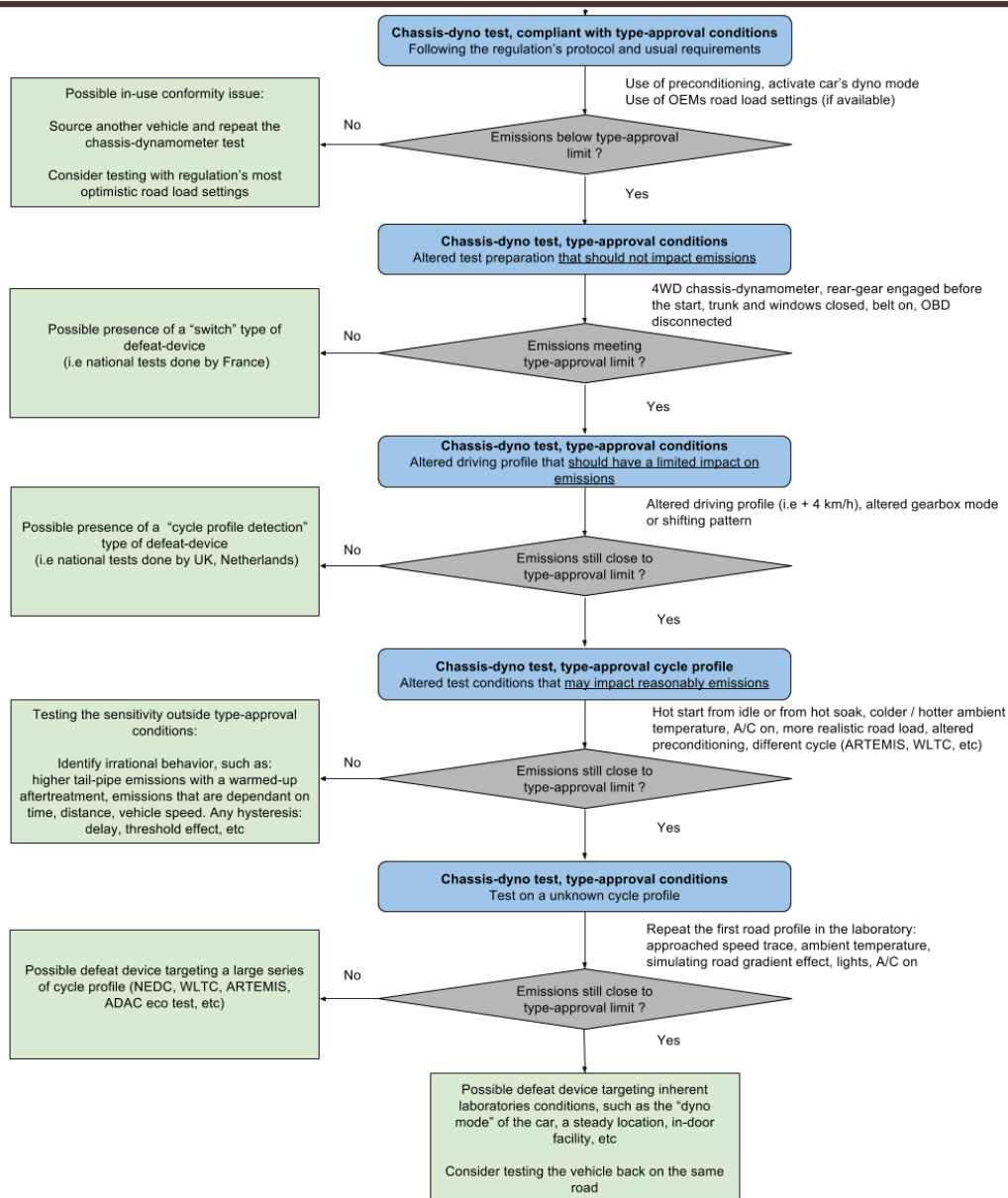
- Chassis-dynamometer test matrix example



Dyno type 4WD or 2WD	Test Cycle	Ambient Temperature	Cold start	AC	OBD link	Remark
2WD	NEDC	25oC	yes	off	yes*	Repeat it at least once
2WD	NEDC	25oC	no	off	yes*	until level**** (constant soaking time between repeats)
4WD (if available)	NEDC	25oC	yes	off	yes*	-
4WD (if available)	NEDC	25oC	no	off	yes*	until level**** (constant soaking time between repeats)
4WD (if available)	NEDC	10oC	yes	off	yes*	-
4WD (if available)	NEDC	10oC	no	off	yes*	until level**** (constant soaking time between repeats)
4WD (if available)	NEDC	25oC	yes	on	yes*	-
4WD (if available)	NEDC	25oC	yes	off	yes*	-
4WD (if available)	NEDC	25oC	yes	off	no	-
4WD (if available)	NEDC X 3	25oC	yes	off	yes*	Repeat NEDC 3x starting from cold start. Do not shut off engine in between runs but idle for the same soaking time used in the other tests.
4WD (if available)	Steady state speed stairstep***	25oC	no	off	yes*	-
4WD (if available)	NEDC	25oC	yes	off	yes*	No pre-conditioning
4WD (if available)	NEDC - modified trace (i.e +2km/h)	25oC	yes	off	yes*	-
4WD (if available)	Artemis urban	25oC	yes	off	yes*	-
4WD (if available)	Artemis urban	25oC	no	off	yes*	until level**** (constant soaking time between repeats)

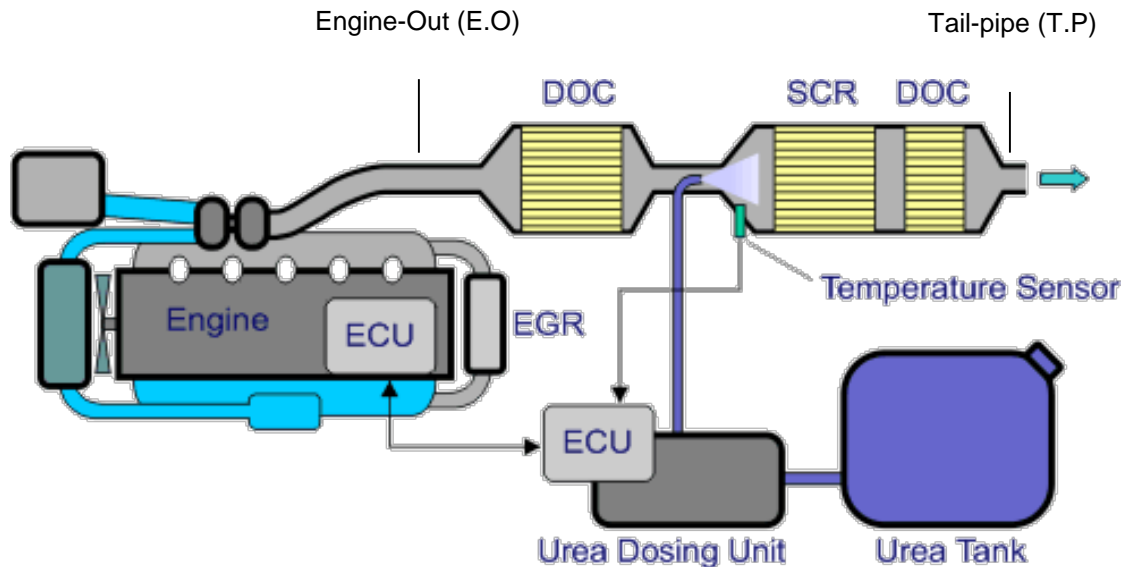
→ Testing with conditions closer to real word

Chassis-dynamometer testing guidelines



Screening campaign: Euro 6 diesel passenger car

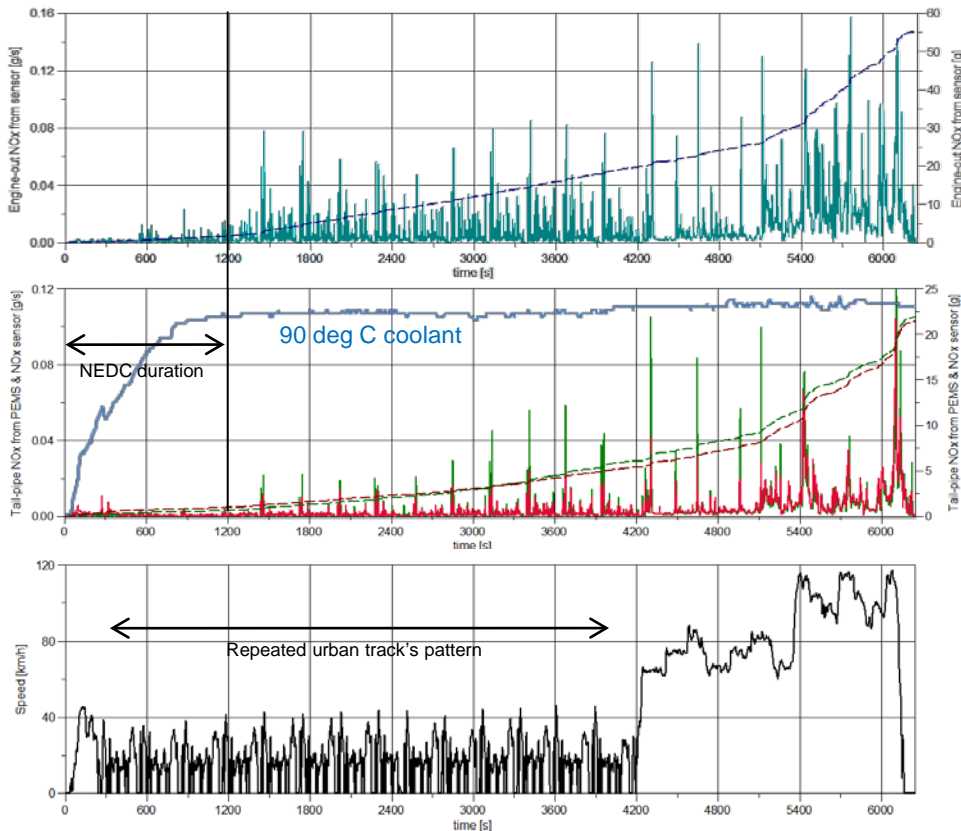
- Test of a passenger car sold across Europe



- Diesel engine equipped with a selective catalyst reduction (SCR) compliant with latest Euro 6b standard
- NO_x type-approval limit is 80 mg/km

Preliminary results of the on-road/track test matrix

- On-track: a mix of urban/rural/motorway combining NO_x sensors and PEMS



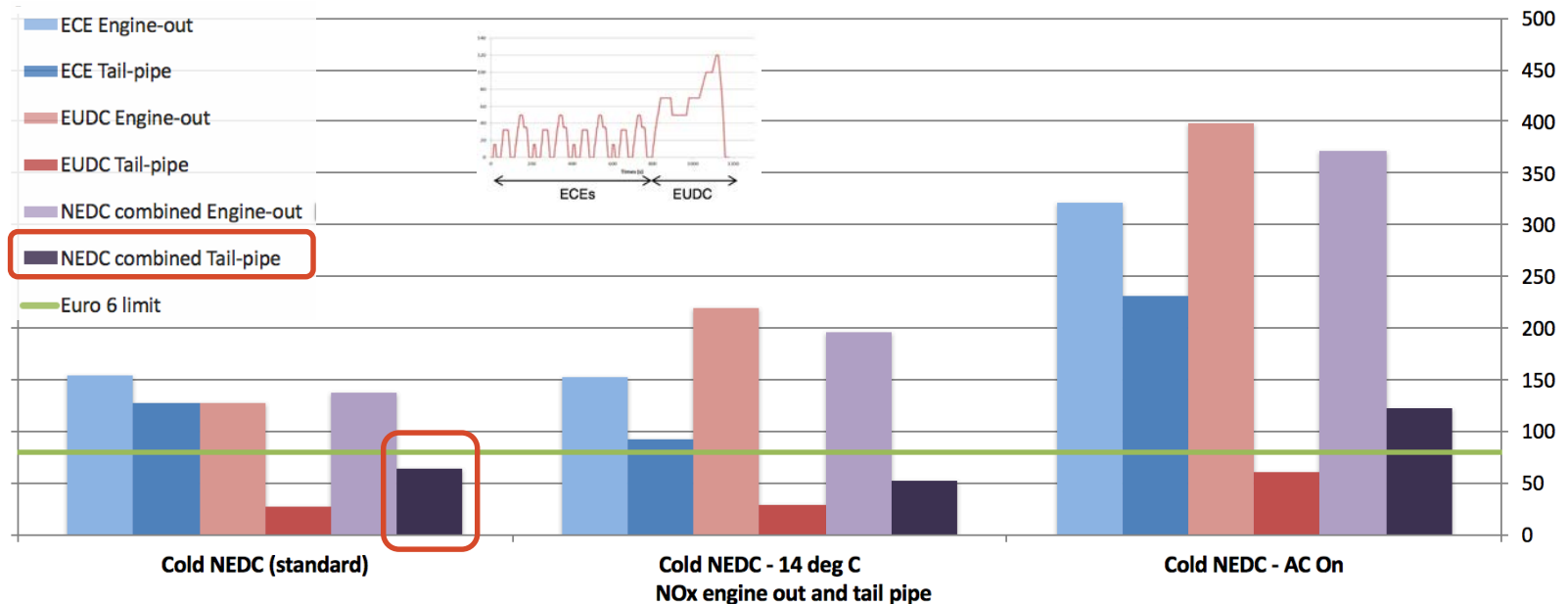
Results	On-track
Engine-out NO _x mg/km	830
Tail-pipe NO _x mg/km	325
SCR NO _x conversion efficiency	60 %
Ratio to Euro 6 limit	4x

- NO_x engine-out and tail-pipe rate increase with time and as the engine gets warmer**, even though the same urban track's pattern is repeated

Preliminary results on chassis-dynamometer

- On chassis-dynamometer:

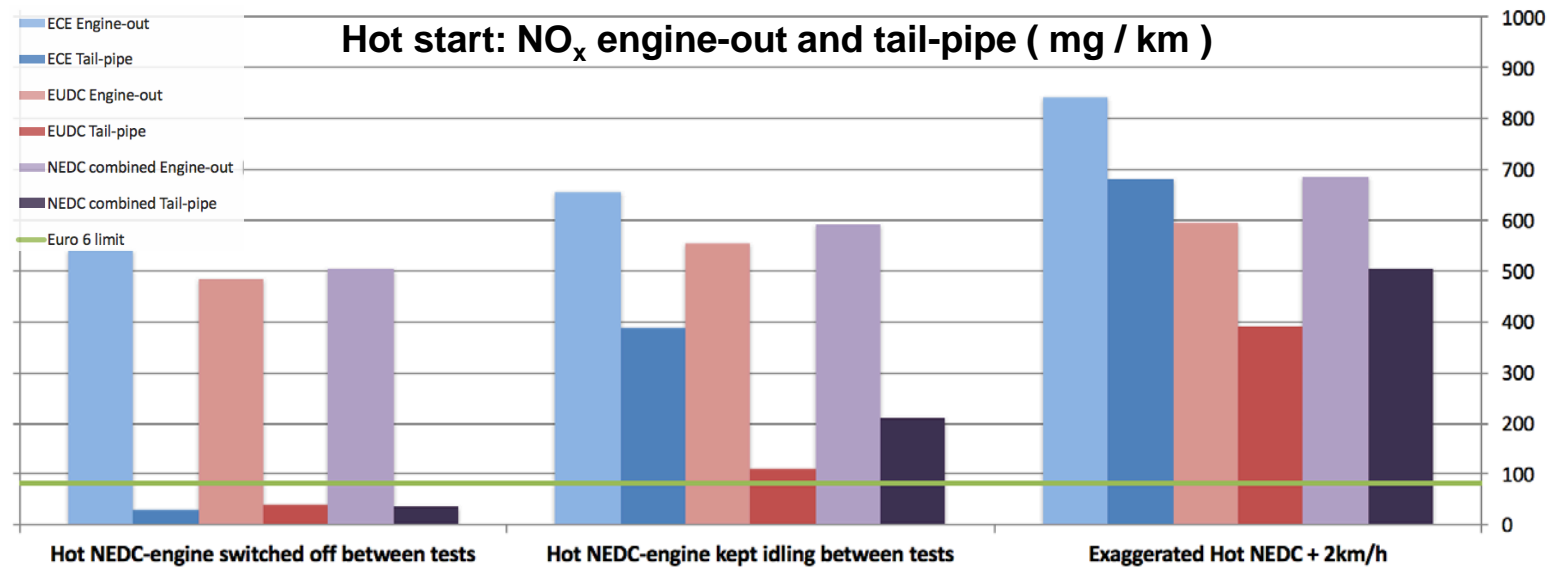
Cold start: NO_x engine-out and tail-pipe (mg / km)



- Cold start results are in line with the limits, and repeatable
- Test at lower ambient temperature at 14 deg C does not impact emissions results
- The standard test was repeated but with A/C on . NO_x engine-out and tail-pipe increase significantly and exceed the limit by 50 %

Preliminary results on chassis-dynamometer

- On chassis-dynamometer



- The hot engine start test confirms the use of a high NO_x engine-out strategy. But a highly efficient conversion from the aftertreatment brings emissions below the limit
- The hot test is repeated, but the engine is kept idling** after the cold NEDC. That condition affects more significantly the results, mainly due to lower aftertreatment conversion
- The **hot test from idling** is repeated with an **altered NEDC profile (+2km/h)**. Engine-out emissions increase can be linked to the increased load. But NO_x conversion from the aftertreatment drops abnormally below 30 %, leading to emissions more than **6x** the regulatory limit, and 14x higher than during a hot start from a switched-off engine

Conclusion and outlook

- National testing by members states in EU have confirmed the high real-world NO_x emissions of diesel passenger cars
- The prevalent usage of defeat devices in EU was established, but claiming their illegality have failed so far
- A defeat-device preliminary screening protocol was presented, testing from on-road (NO_x sensor, PEMS) to chassis-dynamometer
- Results of such protocol were presented on a Euro 6 vehicle, showing NO_x emissions up to 6x the regulatory limit without a substantial rationale for that behavior
- Up-coming real driving emissions (RDE) regulation associated with the future obligation to disclose auxiliary emission strategy will provide stronger enforcement capabilities, at the condition that type-approval authorities can assess their necessity
- But conducting tests outside RDE boundaries conditions will remain important in the future to ensure low emissions in the real world.