The European Commission's science and knowledge service

Joint Research Centre

JRC 2019 PEMS margin review

Final presentation

26 February, 2020

RDE IWG meeting

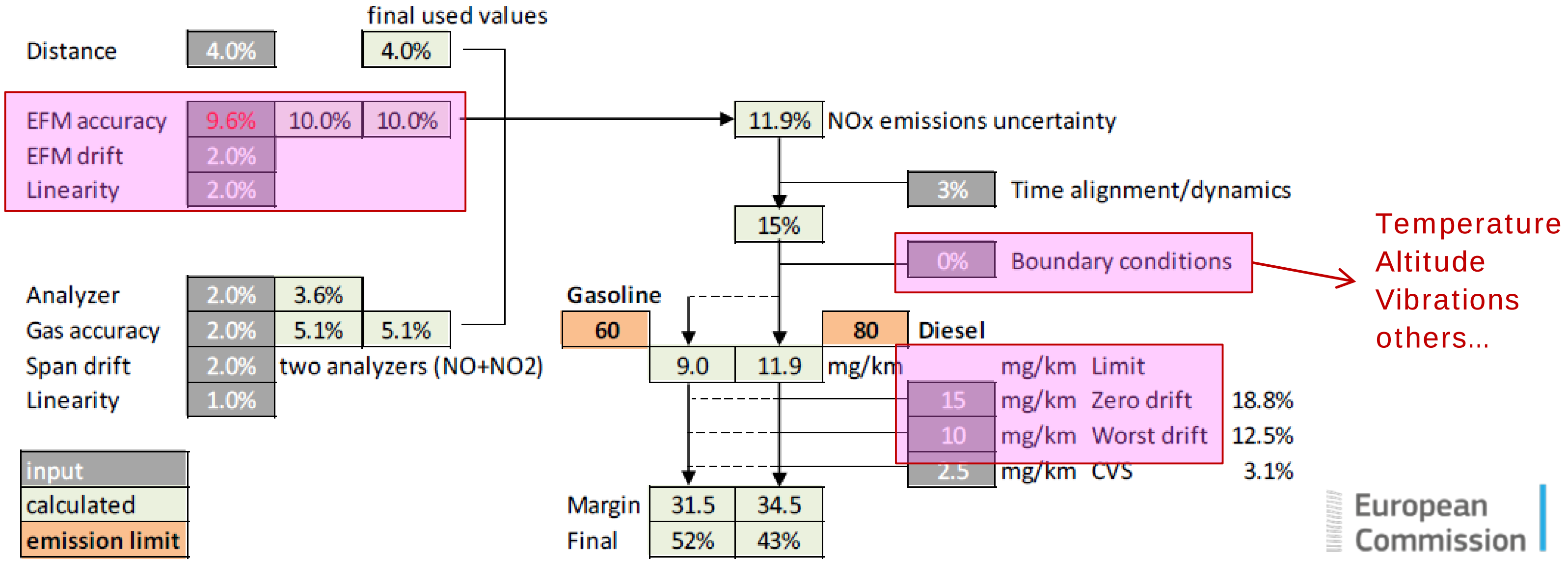
European Commission

PEMS uncertainty assessment


JRC TECHNICAL REPORTS

Real driving emissions:
2017 assessment of Portable
Emissions Measurement Systems
(PEMS) measurement uncertainty

- 2017 JRC framework to evaluate PEMS uncertainty.
- **Exhaust flow meters (EFM)** accuracy concerns
- **Zero drift development:** due to lack of technical evidence 2 scenarios for zero drift were proposed: Step drift (= worst case drift) vs linear drift
- **Boundary conditions** (temperature, altitude) were assumed to have no additional effect on the performance of PEMS



Exhaust mass flow (JRC data)

n = 20	r^2	a_1 slope	a_0 intercept	SEE
Permissible tolerance	≥ 0.90	[0.925/1.075]	[-3.0/3.0]	0.1
Average	0.945	0.929	1.347	0.017
Median	0.968	0.933	1.067	0.018
Outside limit [%]	5	30	10	0

- Overall good correlation of exhaust mass flow
- Slope is the critical element in the pass/fail validation
- Further data needed (other EFM manufacturers, new systems, large engines)
- <u>Not compared against traceable standard</u>

Exhaust mass flow

- Evaluation of the EFM drift showed that it was negligible (before-after test comparisons)
- JRC comparisons gave differences higher than 3%
- Concerns from other stakeholders that EFMs have higher uncertainty than 3%

- **PROPOSAL: Keep 10% EFM uncertainty**

NOx zero drift development over a test

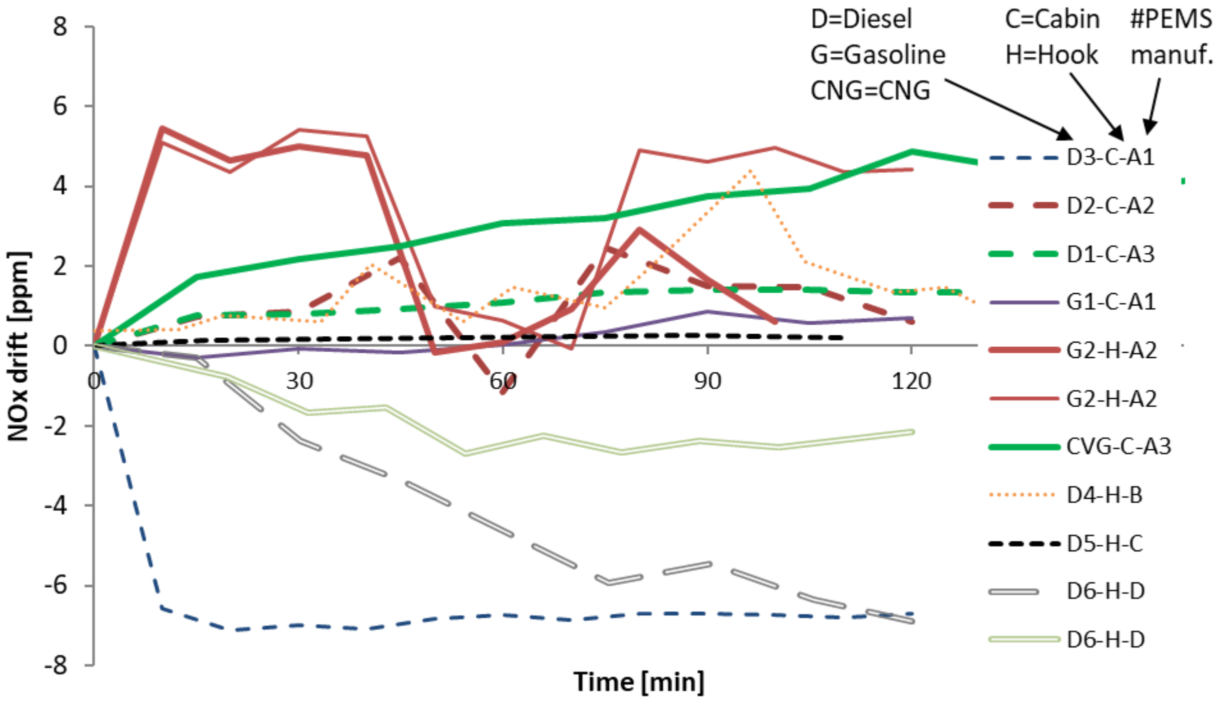
NOx zero drift JRC PEMS campaign

- Objective: gather experimental data to assess the zero drift of PEMS gas analysers under working operating conditions
- Instruments: Four commercial PEMS unit from the same manufacturer installed in the trunk or in the trailer hook. CO/CO_2: NDIR analyser. NO/NO_2: NDUV or CLD analysers.
- Operation:
  - standard preconditioning. Soaking of the vehicle inside facility (20°C).
  - standard pre-test and post-test checks
  - N_2 bottle placed on-board the vehicle used to perform regular zero checks at fixed intervals (10 or 15 minutes, depending on the test) with vehicle running. Each zero check lasted ~ 1.5-2 minutes. Bottle connected to zero inlet of instrument.
  - vehicle driven on RDE-compliant route and not compliant (altitude) routes
  - 30 tests around JRC Ispra site in the period of May 2018 – Jan 2020 (0-35°C)
  - 9 passenger cars (segments B and C) and 1 light commercial vehicle
- Additional tests on static conditions inside testing facility
  - vehicle with the engine off/engine on (idling)

NOx zero drift

Two worst cases:
CNG-C-3 and
G2-H-2b

Due to the very limited number of tests for some PEMS which do not include the variety of different testing conditions, comparison of PEMS is not possible



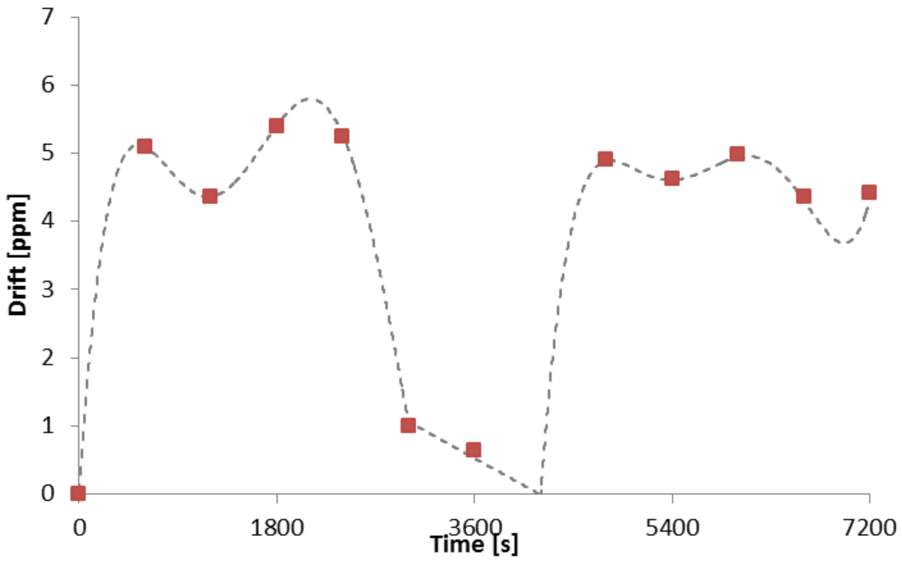
At on-road tests effect of **vibrations** is also included
Ambient temperature range **0-35°C**

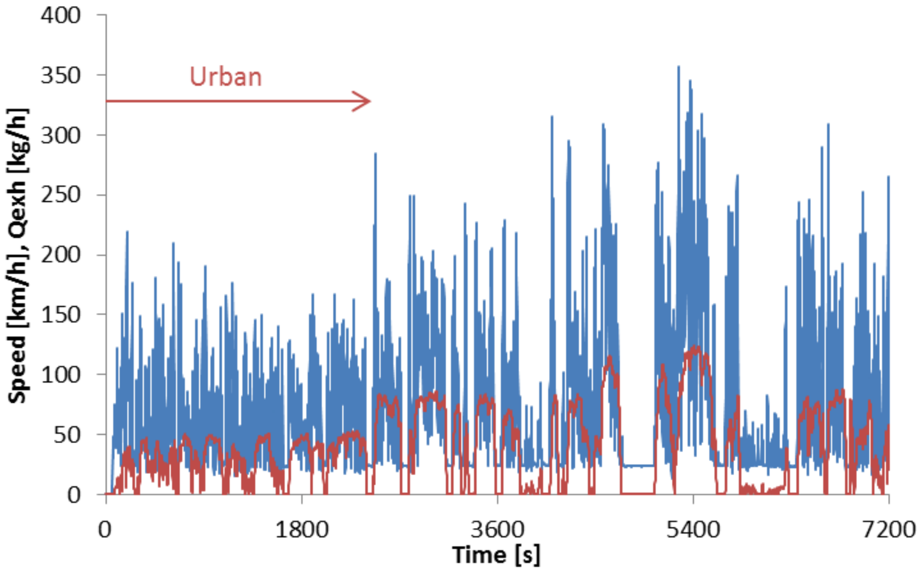
Worst combination (high exhaust flow & drift)

Drift equation was fitted, Real exhaust flow rate and speed were used

Zero drift contribution: Urban **+15.9** mg/km (19-27%)

Complete cycle: **+11.3** mg/km (15-20%)





Conclusions on zero drift assessment

- No apparent drift for CO_2 and NO_x
- No homogeneous NO_x drift behaviour: no drift, linear drift, some up and down steps.
- NO_X step drift (worst case scenario) is not verified.
- NO_X drift contributes up to 10 mg/km in RDE NO_X emission (JRC real cases).

- **PROPOSAL: Under worst combination, NO_X drift contributes up to 16 mg/km NO_X emission**

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Boundary conditions on zero drift assessment

Ambient temperature and NOx zero drift

Experimental (laboratory test)

- Periodic zero check (10-15 minutes) with an N_2 bottle connected to the zero inlet of the PEMS
- PEMS mounted on the hook of a vehicle installed in the chassis dynamometer
- Vehicle is with engine off during the whole test
- Climatic chamber set to change from 23 ºC to -7 ºC (reached in 100 minutes), and again to 23 ºC
- Standard pre-test and post-test checks. Drifts within permissible tolerances

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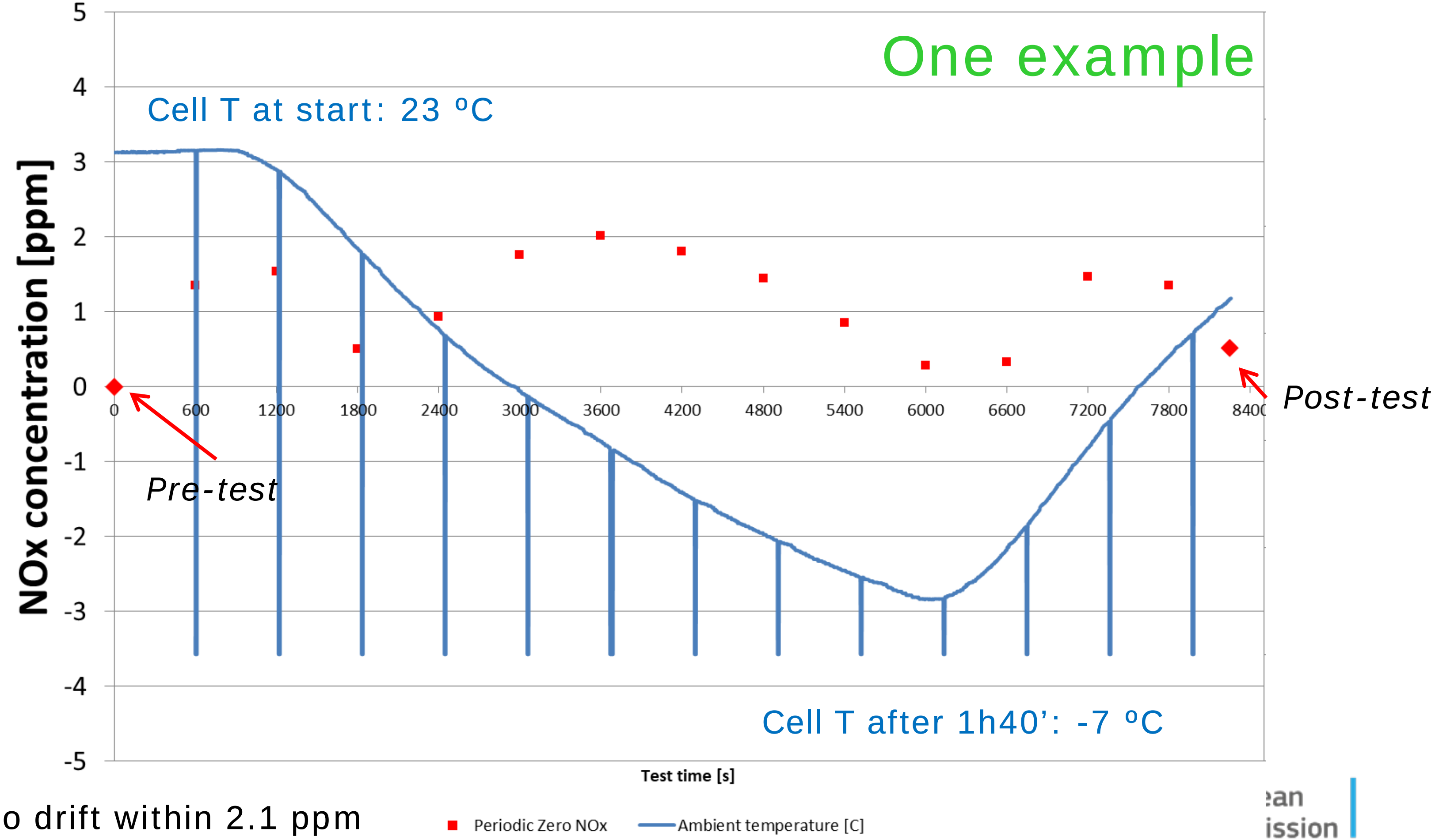
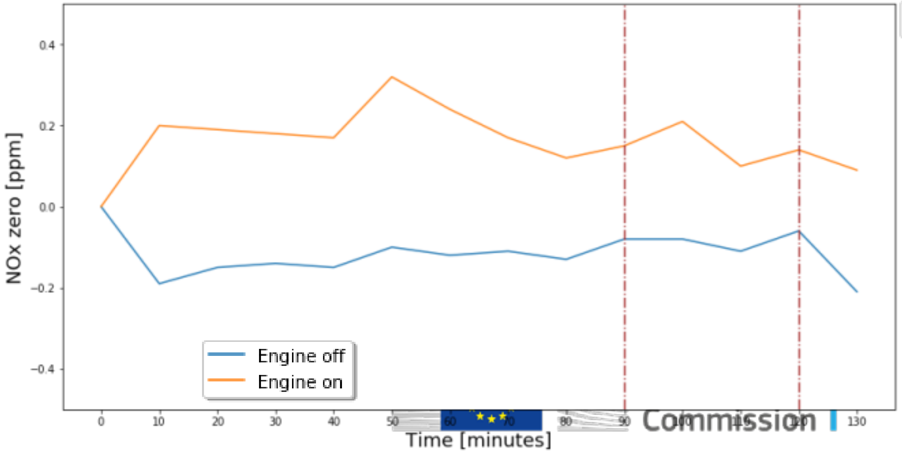
NO_X



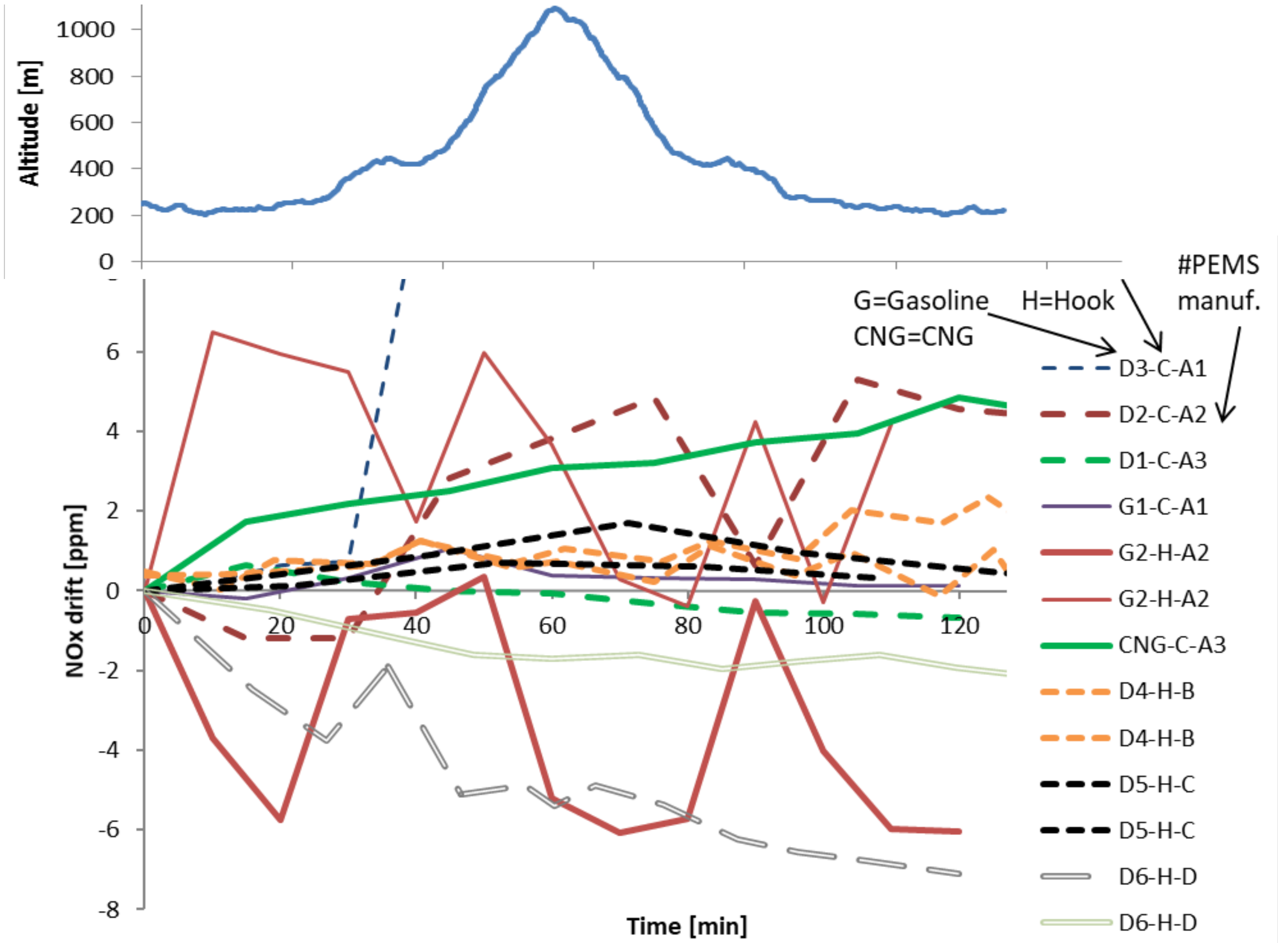
Zero drift within 2.1 ppm

Effect of temperature change on zero drift

- Zero drift does not correlate with ambient temperature change
- No intermediate NO/NO_2 zero drift values exceed the 5 ppm tolerances (always below 2.5 ppm).
- Lack of NOx drift (± 0.2 ppm) was also verified on tests performed at 23 ºC ambient temperature (presented last RDE meeting)



Altitude effect on NOx zero drift



The maximum altitude was **1100 m,** thus **not compliant RDE**

No apparent relationship between larger zero drift and higher altitude.

The on-road tests include the influence of **vibrations** and **temperature 3-34°C**.

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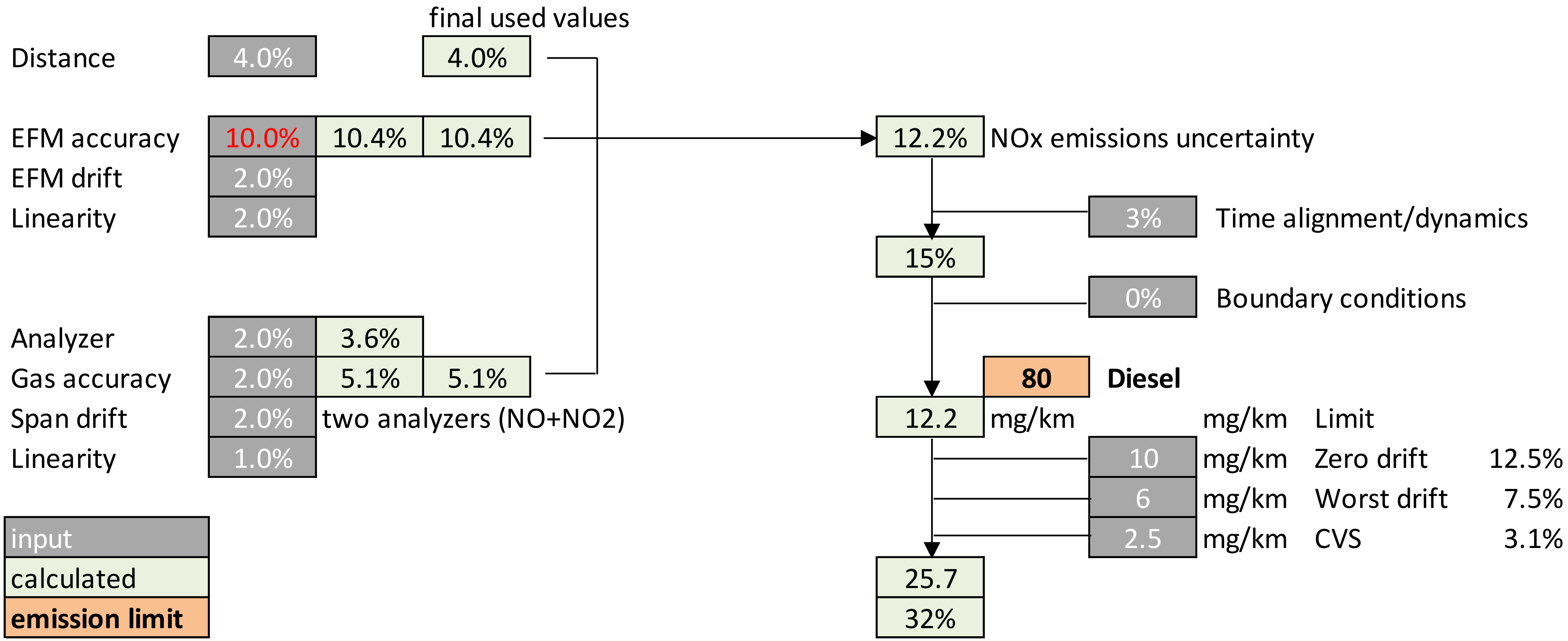
Boundary conditions and zero drift

The limited number of data in terms of number of tests and PEMS manufacturers evaluated, so far showed:

- Limited effect, if any, of ambient temperature (some with sudden temperature change at one PEMS)
- Limited effect, if any, of altitude
- No apparent effect of on-road vibrations (more studies are needed)

PROPOSAL: Based on JRC testing the boundary conditions effect on zero drift should be kept 0: The 5 ppm drift was not exceeded and thus the influence of the boundary conditions are covered in the 5 ppm zero drift margin.

NOx margin estimation



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Conclusions

- The 2019 NOx review focused on the 2018 open issues
  - Exhaust Flow Meter (EFM)
  - Boundary conditions
  - Analyser's zero drift
- The results showed that the conservative 10% uncertainty of EFM should be kept.
- Dedicated on-road zero tests every 10-15 min showed that in most cases the step zero drift is not happening (4 PEMS manufacturers)
- Based on the worst case experimental zero drift and a large engine a worst case zero drift of 16 mg/km was estimated.
- The boundary conditions influence can be included in the zero drift
- A 32% margin was calculated at 80 mg/km

Final remarks

- JRC tested four manufacturers that probably cover 100% of the market in Europe
- Current knowledge at JRC shows that lowering the margin to 0.32 is possible
- There is evidence than in a few cases (step drift of large engines <1%) this margin might be exceeded.
- The change is due to better understanding of how the zero drift can evolve over at a test and not due to changes at the PEMS equipment.
- Due to the very limited number of tests for some PEMS which do not include the variety of different testing conditions, comparison of PEMS is not possible
- The new 0.32 margin is valid for current generation of PEMS instruments