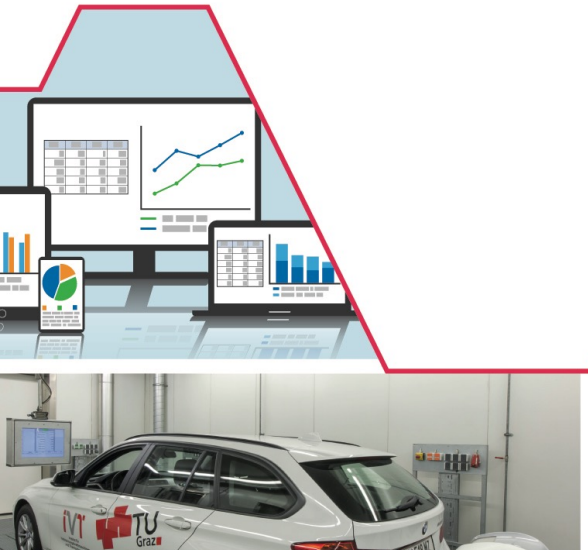
Trends in exhaust and non-exhaust particle emissions in road transport

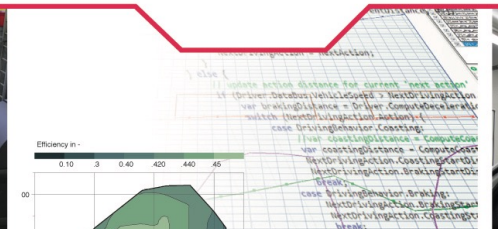
27th ETH Nanoparticles Conference, Jun 2024

Lukas Landl, Stefan Hausberger, Enis Ketan, Martin Opetnik

TU Graz

12.06.2024





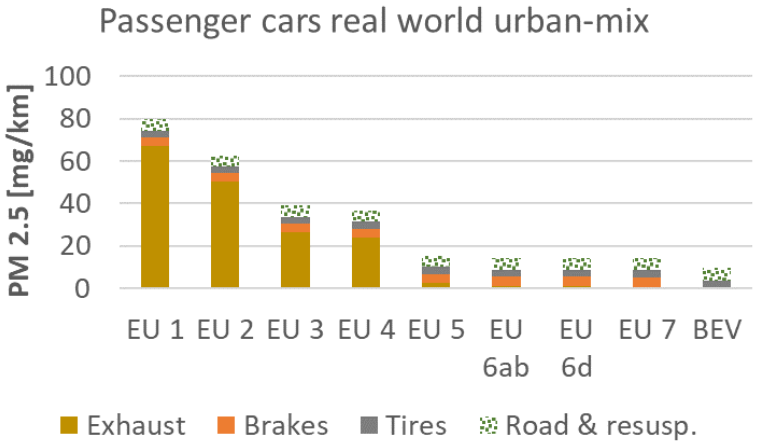
Content

- Introduction
- Simulation methods
- Data sources
  - Literature and data collection
  - Vehicle tests
- Some results
  - Impact of vehicle technologies and traffic situations
  - Trends in exhaust and non-exhaust particle emissions in EU 27

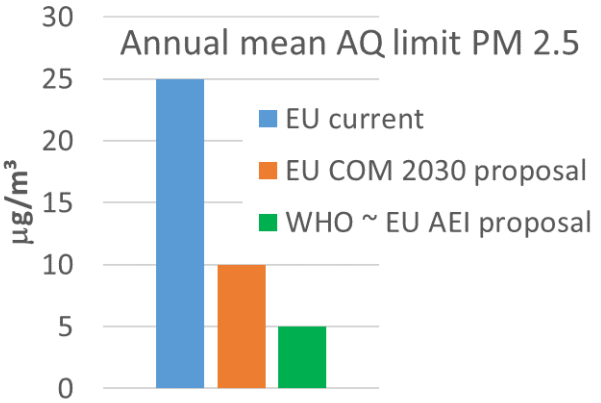
Introduction (1/2)

Exhaust emissions of vehicles drop

→ Traffic PM dominated by Non-Exhaust



Air Quality targets expected to drop even sharper



→ Meeting future PM air quality targets needs reduction of Non-Exhaust Particles (NEP)?

Introduction (2/2)

The next release of the Handbook Emission Factors (HBEFA 5.1) planned for early 2025 shall provide updated emission factors for exhaust and non-exhaust emissions.

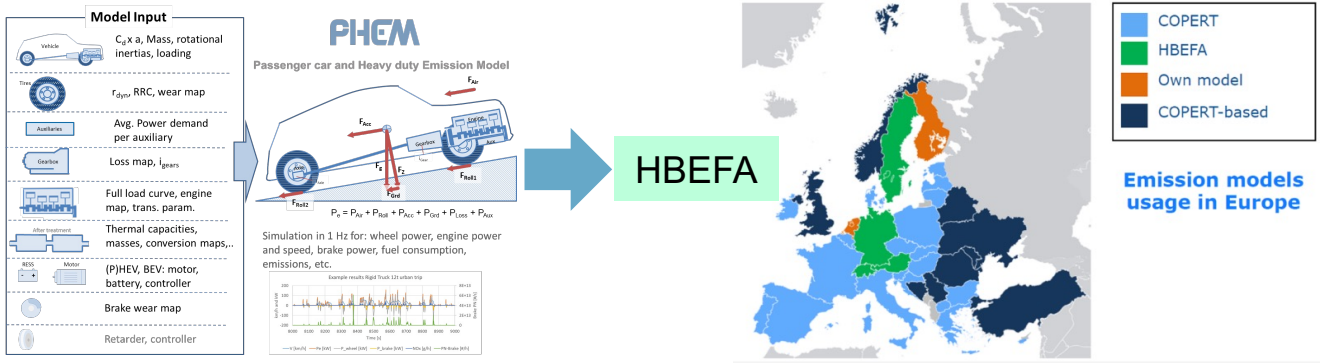
“Emission factors” are real world emissions per vehicle-km for all vehicle categories, propulsion systems, EURO classes and size classes and for fleet average.

Large number of traffic situations covered (>270, each with 7 road gradient classes)
→ vehicle simulation model (PHEM) is used.

Average vehicles are parametrized by large sample for exhaust emissions (> 1200 vehicles)

A similar approach is being set up in PHEM for tyre and brake wear

PHEM provides the energy consumption and exhaust emission factors for HBEFA and parts of COPERT



Simulation targets

Non-exhaust emission factors shall be provided separately for brake-, tyre-, road-wear and re-suspension.

Particle data shall cover TPM, $PM_{2.5}$, PM_{10} and PN_{23}

- for all vehicle categories and EURO classes
- for all relevant traffic situations
- for different vehicle loading and road gradients

TUG is

- developing the methods and software for emission simulation
- coordinating data collection from vehicle and component tests
- running exhaust and non-exhaust emission tests

Measurement activities at TUG-ITnA

- Data collection ongoing
- Test method for brake & tyre wear on chassis dynamometer under development
  - Target: produce data for representative fleet average for airborne brake- and tyre wear

✓ Vehicle on chassis dyno as usual

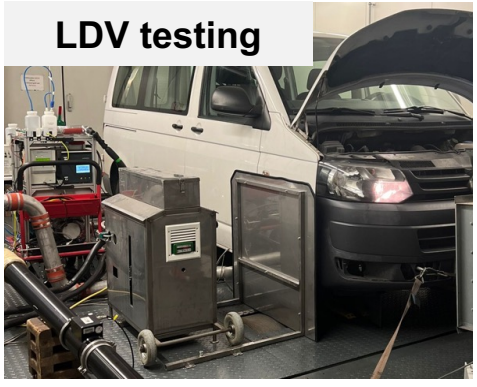
✓ Brakes/tyres housed and ventilated similar to PMP brake test stand method
(but air from test stand is sucked in)

✓ Analysers according to PMP (same as for exhaust)

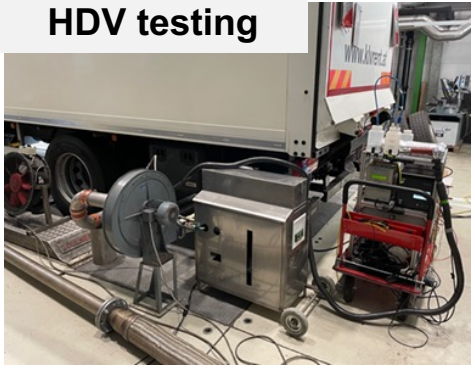
- Retarder activation at HDV to be controlled

– Cooling of tyres is an issue

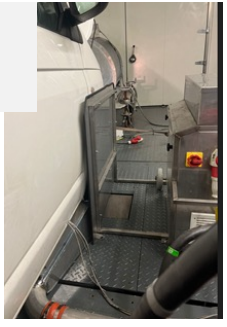
LDV testing



HDV testing



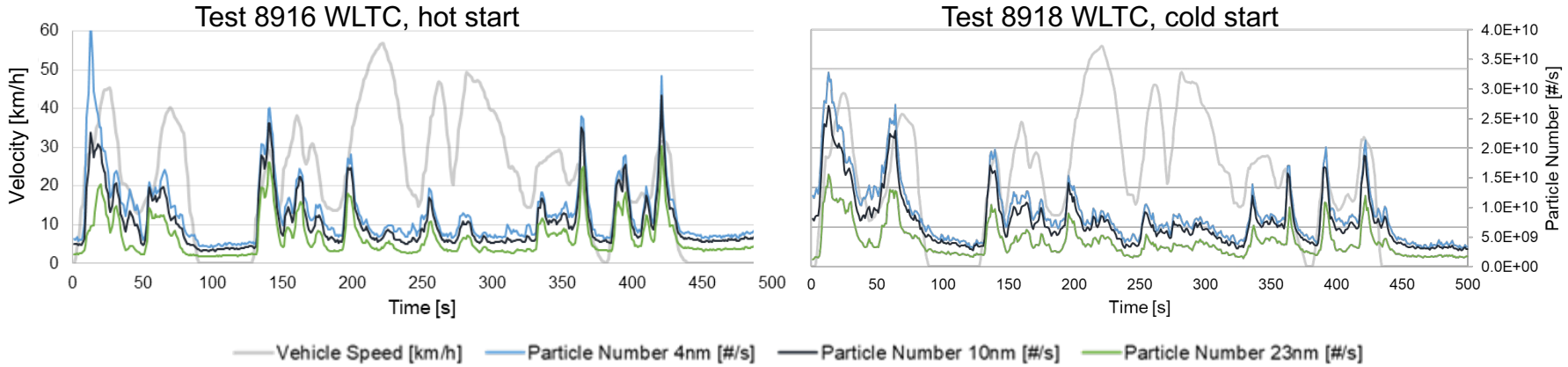
Tyre test set up



Brake test set up

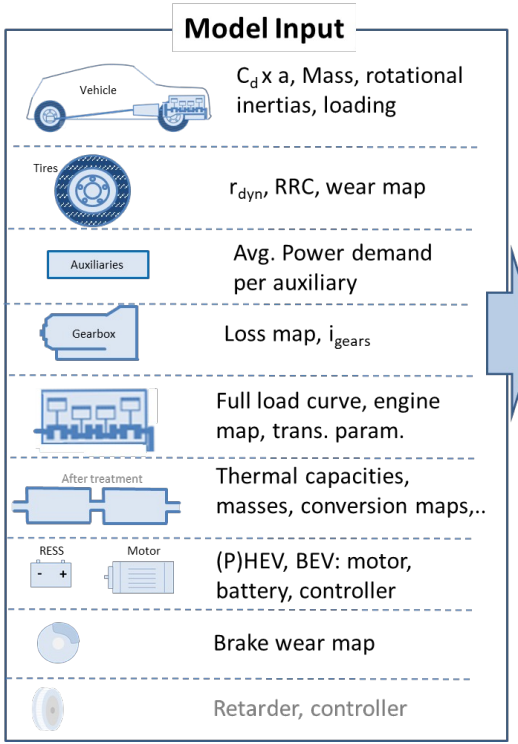
Example for test results from car on chassis dyno

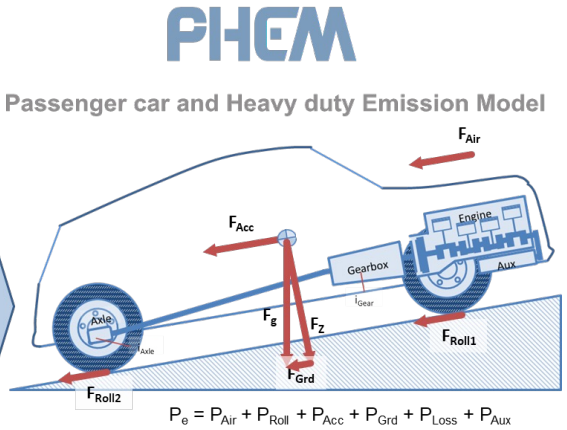
- Test cycles include real world cycles, WLTP and WLTP-brake sub-cycles, different steady state points to test main influencing parameters
- Test results fit with data collected from brake test stand and with literature on tyre wear emissions.
- Findings from tyre tests on chassis dyno:
  - Good repeatability if temperatures well controlled
  - High load points yet only measurable for short time;
    PN flow drops significantly at too high tyre temperatures



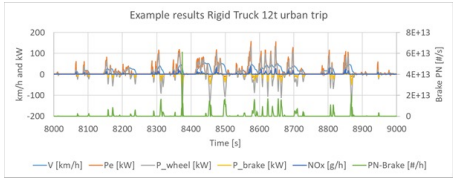
Simulation method used in PHEM

- Brake and tyre wear simulation implemented in our vehicle emission and longitudinal dynamics software tool PHEM.





Simulation in 1 Hz for: wheel power, engine power and speed, brake power, fuel consumption, emissions, etc.



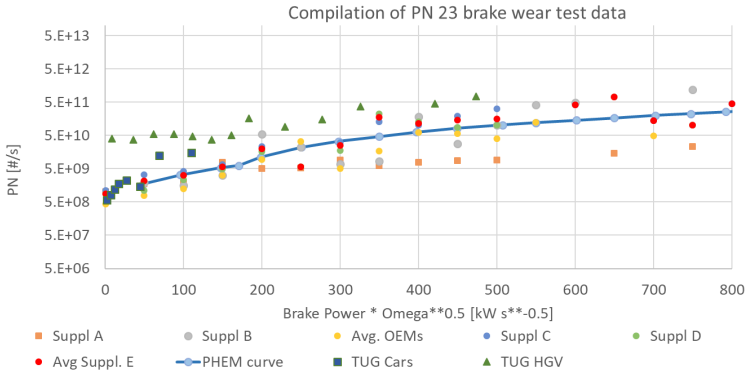
Advantages:

- Representative generic vehicle models for all categories from HBEFA
- Energy flows, power, forces speed, etc. relevant for brakes and wheels simulated based on physical relations
- ICE, BEV, PHEV, HEV with any weight, loading, rated power specifications
- Cars, LCVs, HDVs, 2-Wheeler

Characteristic curves used for brake and tyre wear in PHEM

Brake wear

$PN = F(P, \omega)_{brake}$, $PM = PN \times Density(\omega_{brake})$

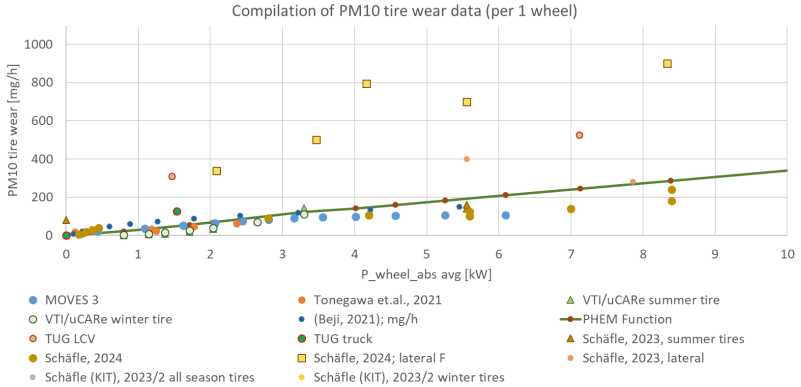


Next steps:

- More pad/disc data to be added (TPM, PM10, PM2.5, PN)
- Temperature effect may be added & switch to emission map

Tyre wear

$PM = F(P)_{friction(1)}$ $PN = PM \times Density$



Next steps:

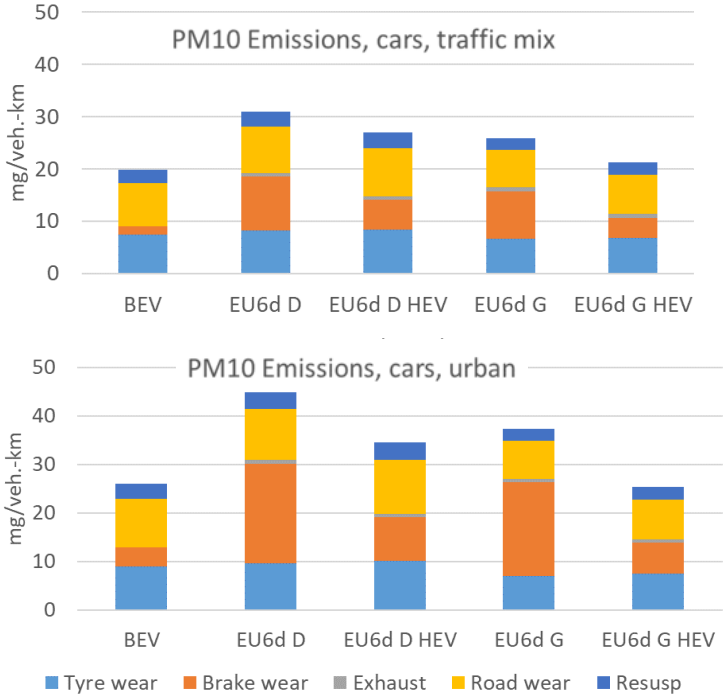
- More test data to be added!
  More detailed simulation of slip in progress
- Add other effects if relevant

(1) In model extended by slip rate

Example for model results for total PM10 in real driving (PHEM$_{13.06.10}$)

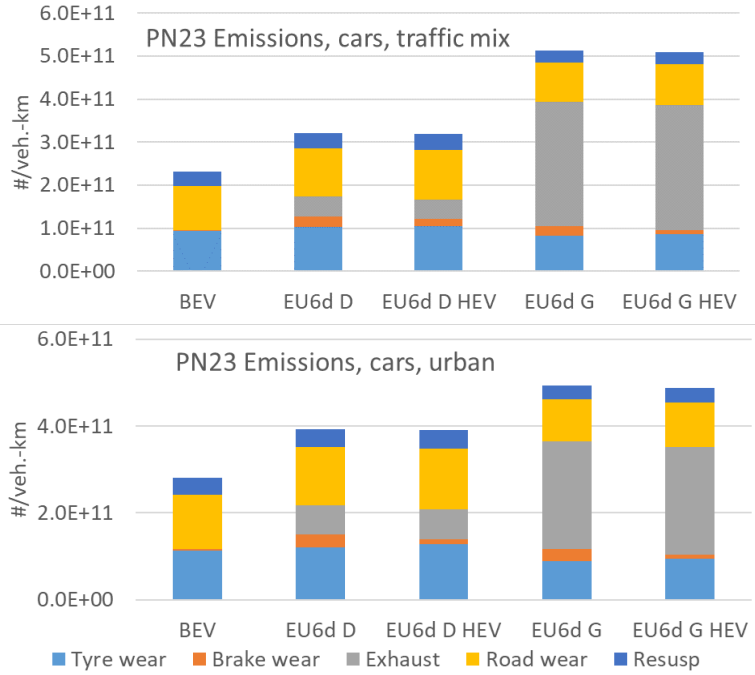
Passenger cars PM10:

Small reduction from BEVs. Electric braking important especially in urban driving



Passenger cars PN:

In contrast to PM10: brake emissions have low, gasoline exhaust high shares of PN

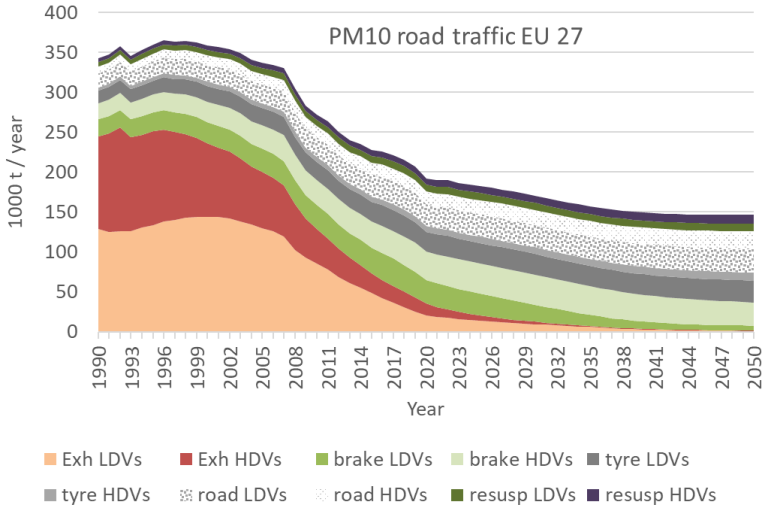


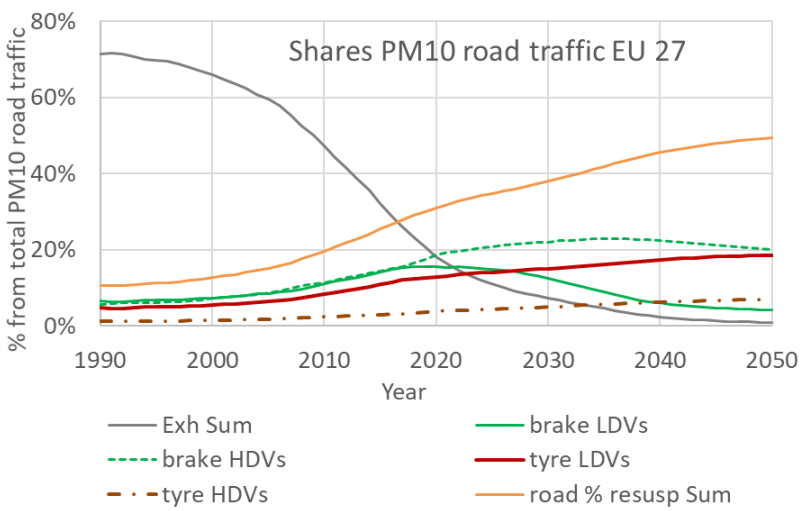
Road traffic simulation results for EU 27

In the framework of H2020 Longrun project (simulate exhaust emission scenarios in EU 27)

Exhaust emissions and LDVs brake wear drop with increasing electrification while tyre wear increases due to increasing traffic volumes and heavier cars. From 2020 to 2040:

- Exhaust PM10 will drop by ca 90% → share drops from ca. 20% to 2%
- Brake wear will drop by ca. 35% → share drops from ca. 35% to 28%
- Tyre wear will increase by ca. 15% → share increases from ca. 17% to 25%
- Total PM10 from road traffic drops by ca. 20% vs. 2020





Summary

- PHEM simulation approach for brake and tyre wear gives realistic results and can differentiate according to driving cycles, vehicle technologies, masses etc.
- More data from brake- and tyre wear tests needed for representative fleet average results! (input very welcome)
- Measurements on chassis dyno can support data collection for brake and tyre(?) wear

First results indicate:

- Exhaust emissions have already less than 20% share on PM10 of road transport
- Brake emissions will drop due to electrification and Euro 7 limits
- Tyre- & road wear & resuspension already account for ca. 50% of PM10 from road transport
- Increasing traffic volumes and vehicle masses lead to increasing PM from tyre and road wear without further measures.
- Future reduction rates of total traffic related PM emissions consequently would be small.

Thank you very much for your attention!

Contact:
Lukas Landl
landl@ivt.tugraz.at