ERMES on Dieselgate: NO\textsubscript{x} Emission Factors reliability for Euro 6 vehicles
Background

• ERMES provides EU road transport emission factors used for science, research, and policy, including monitoring progress (e.g. NECD)

• Reliable emission factors necessary, especially in view of the 40% contribution of road transport and the ongoing NECD revision progress
  – No EU funds for EFs development at least over the 10 last years

• ‘Dieselgate’ accelerated a long-waited review of emission standards effectiveness and emission factors
Impact to Air Quality

EU28: # NO2 stations >40 µg/m3 due to real driving add-on NOx from diesel cars/LCVs

2010:
300 instead of 190 stations ⇔ one third of total...

and 2015:
260 instead of 100 stations ⇔ two thirds of total...

...exceed the NO2 ambient limit value due to “add-on” NOx emissions from diesel cars (and LCVs)
ERMES Statement

- ERMES Issued information paper in Oct. ’16 evaluating latest information
- Currently performs in-depth review of Euro 6 emission levels and collation of new measurements
ERMES Emission Factor Process

Cars & LCVs
- Roller test bench

Trucks
- Engine test bed

RDE
- PEMS

Engine maps

HBEFA Traffic Situations

HBEFA Traffic Situations

Note: VERSIT+ uses only PEMS data w/o modelling since Euro 5/V
Most popular driving cycles used

Regulated cycles: **NOT USED**

Dynamic cycles to feed engine maps: **USED**
New opportunities with PEMS

Equipment carried by the actual vehicle on the road

+ Measurements on the road, real conditions
+ Easy to perform

- Variability of conditions
- Unrealistic vehicle load, aerodynamics
- Variability in emissions level reporting methods
- Easy to perform
In contrast to EURO 5 the number of available modal measurement data for EURO 6 diesel cars is still on a low level (Table 4). In addition, EURO 6 cars already in the market belong to premium classes of vehicle segments which add a certain uncertainty to the resulting fleet emission factors.

In addition uncertainties are related to:

- Shares of $\text{NO}_x$ control technologies in the future EURO 6 fleet.
- Level of exploitation of $\text{NO}_x$ reduction potential of these technologies in the future fleet (e.g. AdBlue may not be dosed at high engine loads by a yet unknown share of vehicle models if not relevant in the type approval test)
Where do we stand at the moment

Significant exceedances of emission limits
- Euro 3: 1.6×
- Euro 4: 2.3×
- Euro 5: 4.7×
- Euro 6b: 2.7×

Good progress in HDV real world NOx due to improved test method (WHTC + PEMS in EU VI)
New measurements available – 1\(2\)
New measurements available - 2

**Final Report**

**WLTP-NEDC correlation exercise**

**M1 Vehicles**

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**Emissions of Euro 5 light duty diesel vehicles**

Swiss emission inventory project, measurement program 2013

By orders of the Swiss Federal Office for the Environment (FOEN)
Collation of new measurements

<table>
<thead>
<tr>
<th>Source</th>
<th>Lab/PEMS</th>
<th>Vehicle Info</th>
<th>Cycle/Phase</th>
<th>Number of tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAT</td>
<td>Lab</td>
<td>PC (M1) 1248cc, Euro 5</td>
<td>NEDC, WLTC</td>
<td>56</td>
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<td></td>
<td>1686cc, Euro 5</td>
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<td></td>
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<tr>
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<td></td>
<td>LCV (N1/I) 1248cc, Euro 5</td>
<td>NEDC, WLTC</td>
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<td>PEMS</td>
<td>PC (M1) 1968cc, Euro 5</td>
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<td>1995cc, Euro 5</td>
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<tr>
<td></td>
<td></td>
<td>1968 cc, Euro 6</td>
<td></td>
<td>12</td>
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<tr>
<td>TUG</td>
<td>Lab</td>
<td>PC (M1) 1995cc, Euro 5</td>
<td>NEDC, WLTC</td>
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<tr>
<td>Dekra</td>
<td>Lab</td>
<td>PC (M1) 2967cc, Euro 5</td>
<td>NEDC, WLTC, CADC, ERMES</td>
<td>34</td>
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<tr>
<td></td>
<td>LCV (N1/III)</td>
<td>1968cc, Euro 5</td>
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<td>52</td>
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<tr>
<td>Horiba</td>
<td>Lab</td>
<td>LCV (N1/III) 2143cc, Euro 5</td>
<td>NEDC, WLTC, ERMES</td>
<td>24</td>
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<tr>
<td>(Ligterink et al. 2012)</td>
<td>Lab</td>
<td>PC (M1) Average of 11 vehicles, 1000 to &gt;2000cc, Euro 5</td>
<td>CADC, Urban, Rural, Motorway</td>
<td>~90</td>
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<tr>
<td>(Fontaras et al. 2014)</td>
<td>Lab</td>
<td>PC (M1) Average of 6 vehicles, 1200 to 2000cc, Euro 5</td>
<td>CADC, WLTC</td>
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<tr>
<td>(Kadijk et al. 2015a)</td>
<td>Lab</td>
<td>PC (M1) 16 vehicles, 1500 to &gt;2000cc, Euro 6</td>
<td>NEDC, WLTC, CADC</td>
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<tr>
<td></td>
<td>PEMS</td>
<td>PC (M1) 2 vehicles, 1750 to 2000cc, Euro 6</td>
<td>Constant speed, Urban, Rural, Motorway</td>
<td>31</td>
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<td>(Kadijk et al. 2015b)</td>
<td>Lab</td>
<td>LCV (N1/III) 1 vehicle, 2100cc, Euro 5</td>
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<tr>
<td></td>
<td>PEMS</td>
<td>LCV (N1/III) Average of 10 vehicles, 1600 to 2300cc, Euro 5</td>
<td>City, Reference, Constant speed</td>
<td>60</td>
</tr>
</tbody>
</table>

**Number of vehicles**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
<tr>
<td>Euro 5 PC</td>
<td>22</td>
</tr>
<tr>
<td>Euro 6 PC</td>
<td>17</td>
</tr>
<tr>
<td>Euro 5 LCV</td>
<td>14 + 6 (EMPA)</td>
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<tr>
<td>Euro 6 LCV</td>
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</tr>
</tbody>
</table>

Euro 5 PC 22

Euro 6 PC 17

Euro 5 LCV 14 + 6 (EMPA)

Euro 6 LCV 0
Euro 5 DPC NO$_x$

- Perfect match of existing EFs with new CADC measurements
- No bias with PEMS
- 60% higher than regulated in urban conditions
Counter-intuitive: cold vs hot-start

System optimisation leads to lower Cold NEDC than hot NEDC emissions
Euro 5 DLCV NO$_x$

- Significantly lower LCV (N1) EFs than PEMS
- Real-world loading presumably underpresented in testing
- Higher-duty cycles in real-world than PCs
Euro 6 DPC NO\textsubscript{x}

- Euro 6 EFs about half of PEMS
- Difference between CADC and PEMS
Hilly route

Trip Start/End: 36m
Altitude: 538m
Main Uphill
Main Downhill
Almost constant altitude

36m
## Euro 6 in extended conditions

### Euro 6 at different driving conditions - LAT

<table>
<thead>
<tr>
<th>Driving</th>
<th>CO₂ (g/km)</th>
<th>CO (mg/km)</th>
<th>NOₓ (mg/km)</th>
<th>CF&lt;sub.NOₓ&lt;/sub&gt;</th>
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<tbody>
<tr>
<td>RDE</td>
<td>150</td>
<td>2.9</td>
<td>360</td>
<td>4.5</td>
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<tr>
<td>Hilly</td>
<td>334</td>
<td>10.7</td>
<td>3907</td>
<td>49</td>
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</table>

### Euro 6 at different temperature - TNO

<table>
<thead>
<tr>
<th>Driving</th>
<th>NOₓ (mg/km)</th>
<th>CF&lt;sub.NOₓ&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>CADC 23°C</td>
<td>26</td>
<td>0.3</td>
</tr>
<tr>
<td>PEMS 2°C</td>
<td>665</td>
<td>8.3</td>
</tr>
</tbody>
</table>
A probable Euro 6 EF evolution

**First, technology showcase models**

- Mainstream Euro 6
- RDE gradual compliance
- RDE with low CF

**NO\textsubscript{x} (g/km)**

- 2012
- 2014
- 2016
- 2018
- 2020
- 2022
- 2024

Worst Case

- COPERT
- Probable
- Euro 6 limit
• SIBYL projects emissions and energy consumption of road traffic in the future for each European country
• Baseline projections are based on scenarios that have reached political agreement within EU
• Historical data based on the EU TRACCS project

• Energy and emission factors for conventional types based on COPERT
• Being used by the European Commission JRC (DIONE) and Industrial partners for assessing the impacts of policies and measures
Euro 6 DPC significance

Up to 60% of total road transport might come from Euro 6 diesel PC in 2035

This may be limited to max 35% if RDE proves successful

COPERT may not be too bad in the long run
Diesel NO\textsubscript{x} not the only issue

- Limited info e.g. on how **aged emission control systems** of both gasoline and diesel vehicles perform

- Continuous trend in South and Eastern EU to convert petrol vehicles to **LPG**; earlier measurements show **significantly elevated emissions** after conversion
  - Already a few million of such cars on the roads

- More information on **non-regulated pollutants** required
  - No NH\textsubscript{3} diesel emission limits, despite urea injection in the exhaust
  - Aged three way catalysts significant sources of NH\textsubscript{3}
  - Benzene, HCB, ... ?

- Issues are also known in the area of **GHG** control,
  - Increasing deviation between real-world and type-approval CO\textsubscript{2}
  - Limited knowledge of N\textsubscript{2}O emissions from deNO\textsubscript{x} control: EMPA study, mean LCV N\textsubscript{2}O over urban conditions up to 28 mgN\textsubscript{2}O/km = 7.6 gCO\textsubscript{2}/km!!!!
Conclusions

• Diesel Euro 6 NO$_x$ EFs expected to vary dynamically with model year
  – Emission control technology mix
  – Gradual compliance with RDE

• Monitoring campaigns necessary to assess progress and to deliver data for reliable EFs
  – Complex emission control systems are sensitive to environmental and operation conditions

• LCVs have not been given proper attention

• Diesel NO$_x$ not the only problem
Further reading


# Measurements allocation

## Euro 5 PC

<table>
<thead>
<tr>
<th>Regulation Cycles</th>
<th>Urban</th>
<th>Rural</th>
<th>Highway</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEDC</td>
<td>30</td>
<td>22</td>
<td>7</td>
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<tr>
<td>UDC</td>
<td>10</td>
<td>5</td>
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<td>WLTP</td>
<td>Low, Medium 20</td>
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<tr>
<td>Real-world cycles</td>
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<td>CADC</td>
<td>Urban 57</td>
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<td>ERMES</td>
<td>Urban 4</td>
<td>EU &amp; Total 8</td>
<td>Motorway</td>
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## Euro 5 LCV

<table>
<thead>
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<tbody>
<tr>
<td>NEDC</td>
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<td>WLTP</td>
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<td>Real-world cycles</td>
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<td>ERMES</td>
<td>Urban 5</td>
<td>EU &amp; Total 10</td>
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## Euro 6 PC

<table>
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Thank you for your attention!