# AVL M.O.V.E

## AVL Aerosol & Gas Measurement Solution

Painsi, Alexander

# Introduction

**Alexander Painsi**
**Senior Business Development Manager**

Aerosol & Gas Measurement

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Over 22 years of engine testing experience in different global positions.

- Development Engineer
- Technical Trainer
- Product Manager
- Senior business development manager for Aerosol & Gas measurement at AVL.

Work focus: Particle and RDE measurement for all areas (LD,HD,NRMM)

# EURO 7 – Actual Status

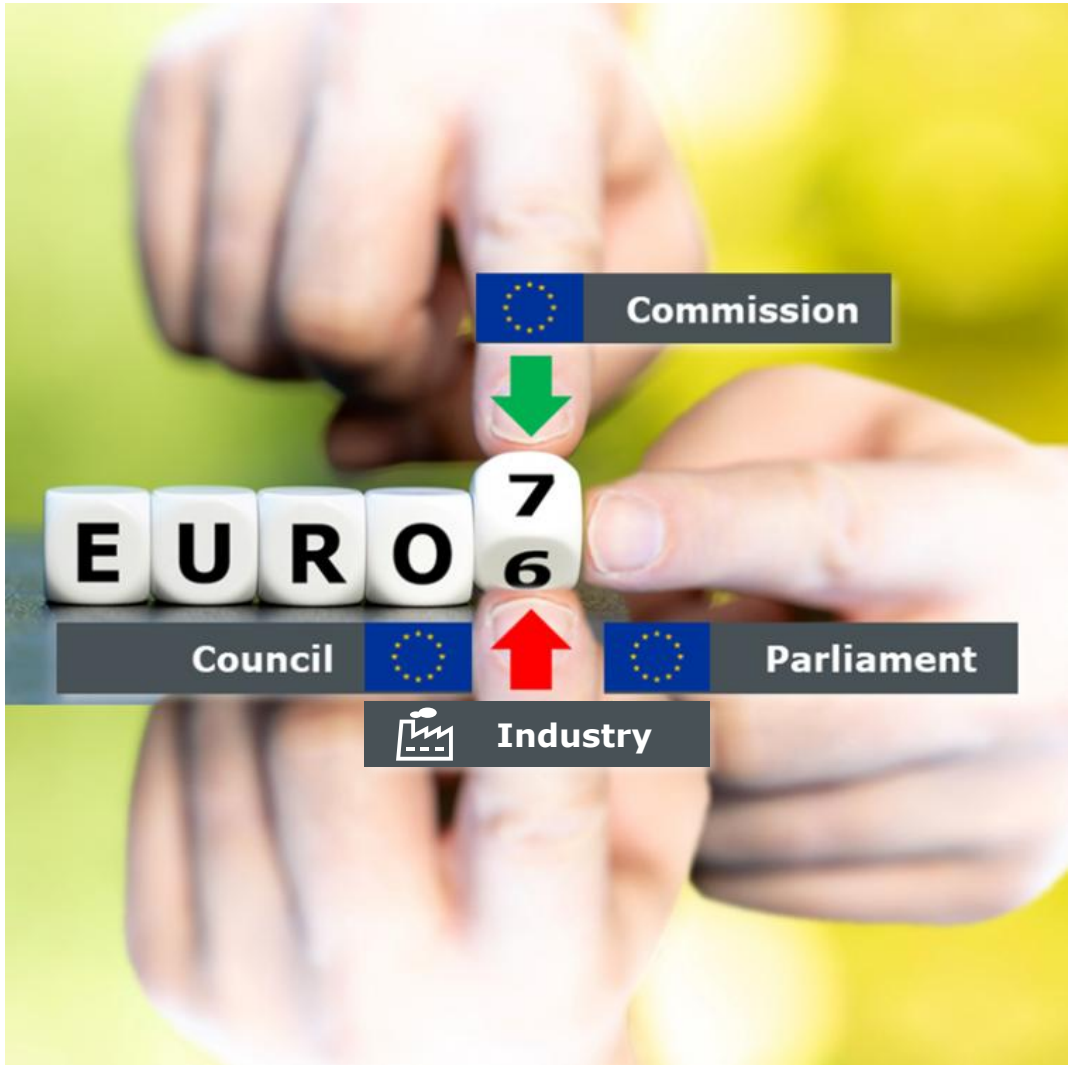

**Trialogue finished:**

- Interinstitutional file published on Dec. 21/ 2023
- Positive vote within ENVI on Jan. 11/ 2024
- Start of AGVES meetings (implementing regulation) on Feb. 05/2024

**Main Changes:**

- PC/ LD:
  - NH3 limit removed
  - THC/ NMHC: unclear if it needs to be measured on the road.
  - Testing conditions, instruments specs based UNR168 (= EU6e)
- HD:
  - HCHO removed, will be reviewed in 12/2027,
  - NMOG: unclear whether it will be calculated or whether HCHO needed
  - CF of 1.5 eliminated, considered in the RDE limit (~30%)
  - Instruments specs based on R49

# Euro 7:




## Euro 7 Legislation:

- After 5 years of consultations, meetings and documents, Europe has reached a general decision about Euro 7. Considering the amount of work done, the outcome is low and does not meet the targets of the European Green Deal.
- **<u>Implementing (technical) details are still open und shall be defined till 2025.</u>**
- Major improvements are implemented for e-mobility and new non-tailpipe emission requirements for emissions from brakes and tiers.
- For pollutant tailpipe emissions there are challenges for heavy duty vehicles, but only minor improvements for light-duty vehicles.

# Euro 7: Requirements

| Euro 7 | | Light-Duty | | | | Heavy-Duty | | | |
|---|---|---|---|---|---|---|---|---|---|
| Implementation date | | **Q4 2026 New types / Q4 2027 All vehicles** Implementing regulations 29.5.02025 | | | | **Q2 2028 New types / Q2 2029 All vehicles** | | | |
| Tailpipe emission on testbed UNR-154 | Limit | wie EU6 mg/km / #/km | | | | **-50%** of EU-VI mg/kWh / #/kWh | | | |
| | Pollutants | CO, NOx, THC, NOx+THC, NMHC, PM, **PN10** | | | | **CO, NOx, NMOG, CH4, NH3 as mass, N2O, HCHO** (HCHO will be reviewed in 2027), PM, **PN10** | | | |
| | Fuel | separate limits for Diesel and Gasoline | | | | - | | | |
| RDE tailpipe emission UNR-168 | Pollutants | CO, NOx, THC, NOx+THC, NMHC, **PN10** | | | | **CO, NOx, NMOG, CH4, NH3 as mass, N2O, HCHO** (HCHO will be reviewed in 2027), **PN10** | | | |
| | Temperature | (-7°C) | 0°C | +35°C | (+38°C) | - | -7°C | ~+35°C | - |
| | Altitude | 700m extended 1.300m | | | | ~ 1700 m (based on abs. pressure) | | | |
| | Driving | Euro 6 limitations with CF | | | | Euro VI limitations, 6% power threshold | | | |
| Non-Tailpipe emissions | **Brake wear** | **WLTP-B cycle, 7mg/km and 3mg/km for PEV** | | | | **Yes** (procedure tbd) | | | |
| | **Tire micro-Plastic** | **Yes,** Tire C1 in 2028, Tire C2 in 2030 (procedure tbd) | | | | **Yes,** Tire C3 in 2032 | | | |
| | EVAP | **1,5g** instead of 2,0g | | | | no | | | |
| **OBM (On Board Monitoring)** | | **NOx, PM** (based on OBD) | | | | **NOx, NH3, PM** (based on OBD) | | | |
| **Anti tampering** | | **Yes** | | | | **yes** | | | |
| Durability-Emission and **battery Battery state of health** | | **Yes** | | | | **yes** | | | |
| CO2, Energy consumption, e-Range | | Chassis dyno testbed based on WLTP | | | | Engine testbed and VECTO simulation | | | |

# AVL M.O.V.E

# AVL on the way to EU7

"CRC conducts 1st on-road vehicle emission study, in Los Angeles, 1956"

**SEMTECH DS**

Cooperation with Sensors Inc.

**AVL M.O.V.E PM PEMS**

Combination of real-time soot & gravimetric PM for US EPA HDIUT

**Gas PEMS iX**

GAS PEMS iX (w. Dual Channel FID)

**M.O.V.E HD**

GAS PEMS 493
System Control
EBOX HD
Auxiliaries

**M.O.V.E iS**

PN PEMS 23nm
GAS PEMS iS
EFM
EBOX iS
Auxiliaries

**M.O.V.E iS+**

PN PEMS 10/23nm sel.
GAS PEMS iS+ w. AVL NDIR
E-Box iS+
Auxiliaries

**M.O.V.E iS+ Euro 7 Extensions**


PN Advanced sel.
GAS Advanced
NH3 PEMS
M.O.V.E FT
System Control Advanced
Auxiliaries

New Regulations

2000 Device

2006 US-HDIUT Gas

2007

2010 US – HDIUT PM

2011 EU-RDE kick-off

2013 EU-ISC Gas

2015 CHN-Beijing NOx

2016 EU-RDE 1+2

2017 EU-ISC Pack 2, EU-RDE 3, EU-ISC NRMM, KOR- RDE

2018 EU-RDE 4, EU-ISC PN

2019

2020 IND-RDE*, IND-HD*, CHN-RDE*, CNH-NRMM$^{ISC}$, CNH-HD VIa

2023 EU EU6e

2025 US Low NOx

2027 EU7 LD, EU7 HD, China 7/VII

Evolution of PEMS Regulations

Complexity

System

# AVL M.O.V.E System – new Solutions

**Test definition (Office)** | **Pre-Test (Workshop)** | **On-Road PEMS testing (Street)** | **Post-Test (Workshop)** | **Result reporting (Office)**

**Test definition**

**System Control Advanced**

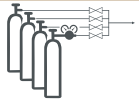
NEW

OBD/GPS/T/P/RH

**Results**

Calculations & Reporting

**Calibration**



Zero and span gas

**Quality Station**

Automated Quality Checks

**Gas Divider**

Gas divider

**Gas Advanced**

NEW

CO,CO2,N2O,NO,NO2,O2

**FID iS+**

THC, CH4

**X-meter**

e-Power flow

**$NH_3$ PEMS**

NEW

NH3

**M.O.V.E EFM**

Exhaust Flow Meter

**PM PEMS**

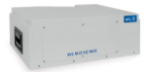
Particulate Matter (for US HD)

**PN Advanced**

NEW

PN-23/10nm

**M.O.V.E FT**



NEW

Multi component system

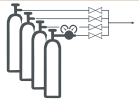
**Plutron/Fueltron**

Fuel/AdBlue Consumption

**Quality Station**

Automated Quality Checks

**Drift Check**



Zero and span gas

NEW New product launch in 2023/2024

# AVL M.O.V.E - EURO 6 ➔ EURO 7 ➔ global RDE

# AVL M.O.V.E - Light Duty System Overview Option A

Supporting tools | Pre-Test | On-Road PEMS testing | Post-Test | Result reporting

**Data Management**

Data mangement system

**Quality Station**

Automated Quality Checks

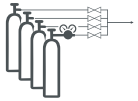
**Gas Divider**

Gas divider

**Online Tools**

helping to master the test

**Calibration**



Zero and span gas

Gaseous emissions:

**GAS PEMS iS+/ GAS Advanced**

CO,CO2,NO,NO2,O2

**FID iS+**

THC, NMHC

**$NH_3$**

NH3

**SYSTEM CONTROL Win10/ SC Advanced**

System controller

**E-BOX iS+**

Central Power supply

**M.O.V.E EFM**

Exhaust Flow Meter

**Ambient/Vehicle**

GPS / T, p, H,/ OBD-II, CAN

**AVL X-meter**

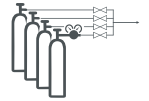
Energy flow

Particle emissions:

**PN PEMS iS (alt. PN Advanced)**

PN-23nm / **10nm**

**Drift Check**



Zero and span gas

**Results**

Calculations & Reporting

EU 7 Additionally required

Optional

- Recommended **Euro 7 Light Duty** Solution, based on "standard" analyzer technologies, **support** of **global** RDE legislations

# AVL M.O.V.E Euro 7 Light Duty System Overview
# Option B – Multi-Component Analyzer

Supporting tools | Pre-Test | On-Road PEMS testing | Post-Test | Result reporting

**Data Management**

Data management system

**Quality Station**

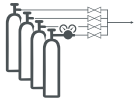
Automated Quality Checks

**Gas Divider**

Gas divider

**Online Tools**

helping to master the test

**Calibration**

Zero and span gas

Gaseous emissions:

**FID iS+**

THC, NMHC

**FT**

NO, NO2, CO, CO2, NH3, N2O, HCHO
(up to 20 pollutants)

**SYSTEM CONTROL Win10/ SC Advanced**

System controller

**E-BOX iS+**

Central Power supply

**M.O.V.E EFM**

Exhaust Flow Meter

**Ambient/Vehicle**

GPS / T, p, H,/ OBD-II, CAN

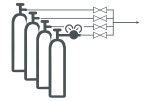
**AVL X-meter**

Energy flow

Particle emissions:

**PN PEMS iS (alt. PN Advanced)**

PN-23nm / **10nm**

**Drift Check**

Zero and span gas

**Results**

Calculations & Reporting

Additionally required

Optional

- For customers who want to **measure additional components** with **less devices**

# HEAVY DUTY PEMS TESTING
# With proven AVL M.O.V.E iS+ portfolio



AVL M.O.V.E PEMS
TESTING

# AVL M.O.V.E Euro 7 Heavy Duty System Overview Option A – Global RDE Compliant

Supporting tools | Pre-Test | On-Road PEMS testing | Post-Test | Result reporting

**Data Management**

Data mangement system

**Quality Station**

Automated Quality Checks

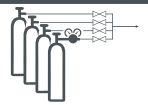
**Gas Divider**

Gas divider

**Online Tools**

helping to master the test

**Calibration**



Zero and span gas

Gaseous emissions:

**GAS Advanced**

CO,CO2,NO,NO2,N2O

**FID iS+**

THC/ NMHC (for NMOG)

**FT**

NH3, N2O, HCHO
(up to 20 pollutants)

**$NH_3$**

NH3

**SYSTEM CONTROL Win10 SC Advanced)**

System controller

**E-BOX iS+**

Central Power supply

**M.O.V.E EFM**

Exhaust Flow Meter

**Ambient/Vehicle**

GPS / T, p, H,/ OBD-II, CAN

**Mounting**

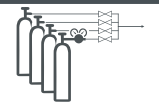
Mounting frames/ damping

Particulate emissions:

**PN Advanced HD**

PN-23nm / **10nm**

**Drift Check**



Zero and span gas

**Results**

Calculations & Reporting

Additionally required

New, launch in 2023

New, launch in 2023, alternative

- Support of **Euro 7 <u>and</u> global RDE** regulations, not all legislations allow new technologies for standard components yet, EURO7 NMOG Determination?

# AVL M.O.V.E Euro 7 Heavy Duty System Overview Option B – Multi-Component Analyzer

Supporting tools | Pre-Test | On-Road PEMS testing | Post-Test | Result reporting

**Data Management**

Data mangement system

**Quality Station**

Automated Quality Checks

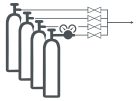
**Gas Divider**

Gas divider

**Online Tools**

helping to master the test

**Calibration**



Zero and span gas

Gaseous emissions:

**FID iS+ PEMS**

THC/ NMHC (for NMOG)

**FT**

NO, NO2, CO, CO2, NH3, N2O, HCHO (up to 20 pollutants)

**SYSTEM CONTROL Win10/ SC Advanced**

System controller

**E-BOX iS+**

Central Power supply

**M.O.V.E EFM**

Exhaust Flow Meter

**Ambient/Vehicle**

GPS / T, p, H,/ OBD-II, CAN

**Mounting**

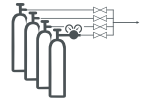
Mounting frames/ damping

Particulate emissions:

**PN Advanced HD**

PN-23nm / **10nm**

**Drift Check**



Zero and span gas

**Results**

Calculations & Reporting

EU 7 Additionally required

New, launch in 2023

- Recommended **Euro 7 Heavy Duty** Solution, R49 Update

# AVL M.O.V.E – THE RDE Testing Solution



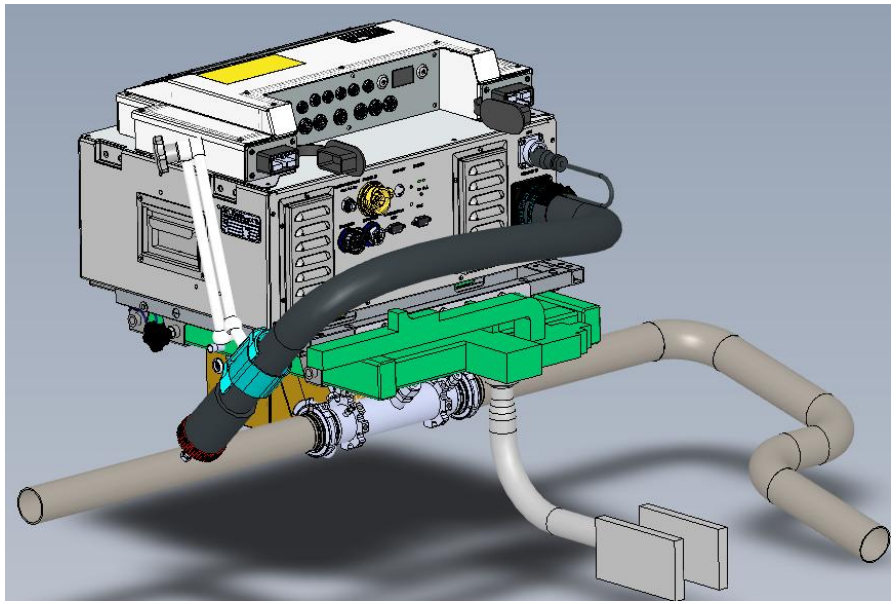
| | |
|---|---|
| **Global "RDE" support** | • **Modular** concept<br>• **Extensions/Alternatives/ Options** available to cover all vehicle applications, worldwide RDE regulations and R&D |
| **Future safe** | • **Improvement** of standard technology to ensure lowest uncertainty<br>• **New technologies** to allow more than 20 components simultaneously<br>• **Electrical Energy** Measurement and Range Testing<br>• **Wide range of ambient** boundaries supported |
| **Cost effective** | • **Re-use and extension** of existing M.O.V.E iS+ possible<br>• **Tailored solutions** acc. to individual needs available |
| **Efficient** | • **Guided and automated** testing workflow<br>• **Automated** data **evaluation** and **report** generation<br>• **Automated RDE** testing **process** |
| **Compliant** | • All known legislative formulas implemented in MDT<br>• **Certificated** tool according legislative requirements<br>• Ready for **corporate Data Management**<br>• **ISO 17025** & **CEN** |

# GASEOUS PEMS

# AVL M.O.V.E FT - Highlights


- FTIR spectrometer for the measurement of **NO/ NO2, CO/ CO2, $NH_3$** (Ammonia), **N2O** (Nitrous Oxide), **HCHO** (Formaldehyde) and more
- **No liquid nitrogen** (LN2) and **no supply gases** needed
- **One box** including pump and everything needed for the FTIR measurement
- **Long-term gas calibration** for each individual FTIR spectrometer with verified accuracy
- **Small** footprint and **lightweight (~18kg)**
- **Stand-alone** or as **add-on to** the well known **AVL M.O.V.E** test system
- **Full integration** into **M.O.V.E System Control**
- **Efficiency gains for R&D: easy mounting + THC approximation + no calibration necessary.**
- **Ready for China 7.**

# AVL M.O.V.E FT – Technical Specification



| | |
|---|---|
| Dimensions: | 495 x 360 x 189 mm |
| Weight: | ~18 kg |
| Power supply: | 24V / 20 A max. w 5m HL |
| Power consumption: | ~150 W (after warm-up @ 20 °C, w 1m HL) |
| Ambient temperature: | -10 °C to +45 °C |
| Ambient pressure: | 800 – 1,100 hPa |
| Humidity: | 5 – 90% |
| Flow rate: | ~5 l/min |
| Response time: | < 2.5 s |
| Data rate: | 1 Hz |
| Spectral resolution: | 0.5 $cm^{-1}$ |

# AVL GAS ADVANCED


- Recommend for **existing** und **upcoming** RDE legislations:
- Uses standard analyzer technology: **Low NOx NDUV** (NO/ NO2), NDIR (CO/ CO2, N2O optional for R&D purpose)
- Based on GAS PEMS iS+ with focus on **high NOx accuracy** at the low range and **low drift**
- **Automated linearization**
- NEW **TEC coating**
- NEW **Purge Connection** behind service flap for easier **maintenance of condensate pump**
- Weight: **~ 27kg**

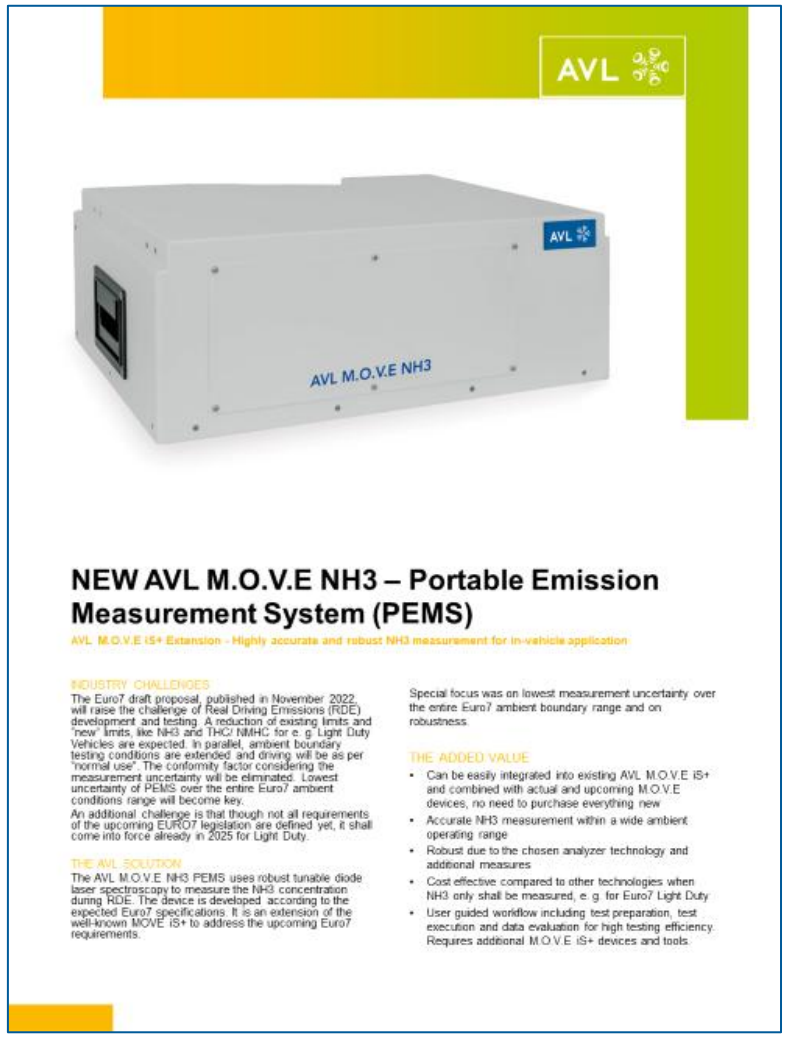
# AVL GAS ADVANCED - Specifications


| Gas Advanced NOx Specifications | |
|---|---|
| Measurement ranges (linearity check range, analyzer can still measure higher concentrations) | NO: 0 – 1,500 ppm (standard calibration)<br>NO2: 0 – 1,000 ppm (standard calibration) |
| Measurement accuracy | NO:<br>0 – 999ppm: **+/-1ppm** or +/-1.5% rel.<br>1000 – 1,500ppm and above: +-2% rel.<br>NO2:<br>**+/-1ppm** or +/-1.5% rel.; above 1,000 ppm: +- 2% rel. |
| Zero drift / 4 hrs. | NOx: **≤ 1 ppm** |

# AVL M.O.V.E NH3 PEMS


- **Low Measurement uncertainty:** Accurate NH3 measurement over a **wide ambient operating** range
- Based on **Laser Spectroscopy**, Tunable Diode Laser, **temperature stabilized**
- Uses highly **sensitive photo-based detector** to ensure **accuracy** over the **entire measurement range**
- **Heated above 170°** to avoid sample artefacts/ condensation of chemical side products
- **H2O compensation** up to 40 vol. % H2O (~ 0.05ppm/ vol. % H2O)
- **ADDON:** if NH3 shall be measured in addition
- Fully **integrated into System Control** (R19, release on 23.10/23)

# AVL NH3 PEMS - Specifications




| TECHNICAL DETAILS | |
|---|---|
| Measurement principle | Tunable Diode Laser (TDLAS) |
| Measurement value | NH3 (ppm) |
| Measurment range | 0 – 1,500 ppm |
| Ambient operating range | -10 °C to +45 °C;<br>700 to 1,050 hPa (~ 0 – 3000 m) |
| Operating voltage | 22 to 28.8 VDC/ appr. 350 W after warm-up |
| Accuracy | 0 - 999: +-1.5 ppm or 1% rel.<br>1,000 - 1,500 ppm: +-2% rel. |
| Zero drift | ≤ 1,5 ppm/ 4 hrs. |
| Weight/dimensions (WxHxD) | ~ 17.5 / ~ 490 × 180 × 330 mm |

# PARTICLE MEASUREMENT

# AVL M.O.V.E PN Advanced LD & HD
# On Road **Particle Counting for 10nm** particles

# AVL M.O.V.E PN Advanced LD & HD On Road **Particle Counting for 10nm** particles

**New EPC Advanced**


- EPC Advanced inside:
  - Measurement of 10/23 nm particle number concentration for Light and Heavy Duty
  - Higher sensitivity, ~ 3 times lower LOD (~ 1,000 #/cm$^3$) compared with PN PEMS iS
  - Max. measurement range: 7*10$^7$ #/cm$^3$ (2* times higher)
  - ➢ New electronic filter supports further improved correlation
  - Extended linear sensor range to better cope with cold start peaks
  - **Upgrade** of existing devices possible

# INTEGRATION

# System Control Advanced


- **“Heart” of AVL M.O.V.E**
- **Robust design** for mobile use, **MIL Standard**
- Wide **operating temperature** range (–20 … 60 °C)
- **External digital GNSS (=GPS) and ambient sensors**
  - **can be calibrated w/o System Control**
- **2*times better computing power** compared to the predecessor
- Integrated **smart battery** to avoid **data loss**
- **TPM Chip** for solid state **disc encryption** to support **IT security** needs
- Seamless and **automated** RDE process with the **AVL In-Vehicle Data Management Solution**
- Central operation of devices and data acquisition
- Secure data transfer with signed certificates

# System Control Advanced – Technical Specs

## Main Specification

CPU: Intel® Core™ i3-9100HL

**256GB SSD**

2x 1000Base-T Ethernet on 10-port Gbit-Switch

Wi-Fi 5 (802.11/a/b/g/n/ac)

**Security: TPM 2.0**

Backup Energy: **Smart battery integration**

## Interfaces

Frontside:

- 2x standard USB plugs (Type A)
- **1x Standard Display port**
- **1x Standard DVI port**
- **2x Standard Ethernet ports**

Backside:

- **4x USB 3.1 Fischer plugs**
- 2x Standard USB 3.1 plugs
- 1x Power In
- 8x Ethernet (ODU)
- 1x RS232

# AVL M.O.V.E QUALITY STATION
# **Boost your Efficiency** in PEMS testing


**Automated Checks** (via System Control):

- **Response Time** checks
- **Linearity Checks** with AVL GDU Dividers (incl. new GDU SL)
- **Automated pre-/ post test**, zero/ span checks with single and mixed gases
- Connection of **up to 10 single gas** cylinders possible + Synthetic Air/ N2 in

**All AVL M.O.V.E GAS PEMS systems** are supported :

- GAS PEMS 493/ iX
- GAS PEMS iS/ iS+
- FID iS+
- Will remain compatible with future AVL MOVE devices

# POWER SUPPLY

# Power Supply

# M.O.V.E Power – Flexible Power Solutions

## EBOX iS

- Max. 2 measurements devices in addition to EFM and System Control:
  - **Power Out:** 2*30A, 3*10A + 5*Ethernet
  - Support of **Li-Ion batteries only** (no AGM)
  - **Weight:** ~2kg

## EBOX iS+

- Up to 4 measurements devices in addition to EFM and System Control:
  - **Power Out:** 4*30A (**from Rev. 15 on**), 4*10A, 2*2A power outputs + 5*Ethernet
  - **Weight:** ~ 5kg
  - **"Wired" Remote on/ off** with SoC (voltage) indication
  - **Support of Li-Ion** or **AGM batteries**

## EBOX iX

- Required for GAS PEMS HD/ iX, in addition, either a PM PEMS or a NH3 PEMS, MOVE FT can be connected:
  - **Power out: 1*60A (GAS PEMS 493/ iX), 1*30A, 1*20A, 4*10A, 2*2A power outputs + 5*Ethernet)**
  - **Weight":** ~ 6 kg
  - **"Wired" Remote on/ off** with SoC (voltage) indication
  - **Support of Li-Ion** or **AGM batteries**

# Power Supply – EURO7/ EURO VI/ 6e

**EBOX iS+**


**Battery box w 4 Li-Ion**

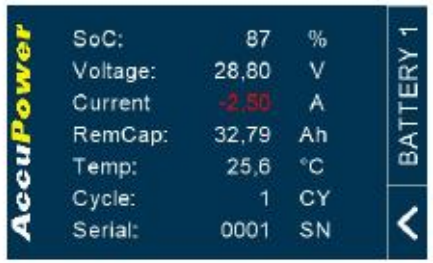

**100A MV ChargeMaster**

- Up to 4 Boxes with each 4*Li-Ion can be directly connected to the EBOX iS+
- Hot swap of batteries possible: pre-request: either battery charger or a battery box with remaining capacity
- Nominal capacity: 150Ah for ~ 3.5 to 4hrs testing (3 devices);
- Weight of the battery box ~ 30kg incl. 4 batteries

| Pack Specifications | |
|---|---|
| Nominal Voltage | 25.9 V |
| Capacity (Nominal) @0.5C | 150.8 Ah ±6%. |
| Energy | 3905 Wh |
| Weight | 29.6 kg. ±500g. |
| Size, Max. (L x W x H) mm | 499x x 394 x 192 ±6 |

| Operating Specifications | |
|---|---|
| Operating Voltage | 21.0 V to 29.4 V |
| Charge Voltage | (**Max**. 29.4 V) ±0.6V |
| Discharge End Volt. | 21.0V |
| Operating Temperature:<br>Discharge<br>Charge | <br>-20°C to 50°C<br>- 10°C to 45°C |
| **Max.** Discharge Current | 72A @ (-10°C-55°C)<br>100 A ±5A (Peak) |
| **Max.** Charge Current | 72A @ (-10°C-45°C)<br>100 A ±5A (Peak) |

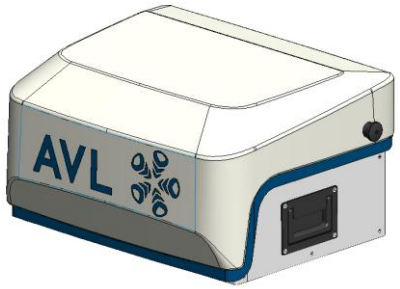
**Embedded battery management with data monitoring: Optionally one pcs. for each location?**

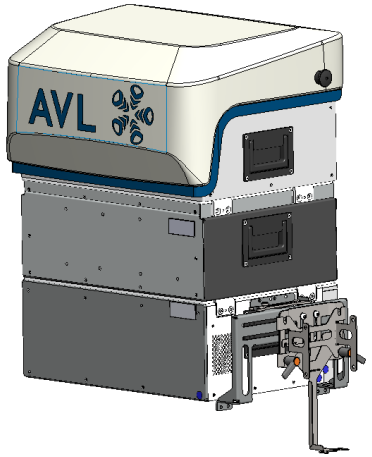


# MOUNTING

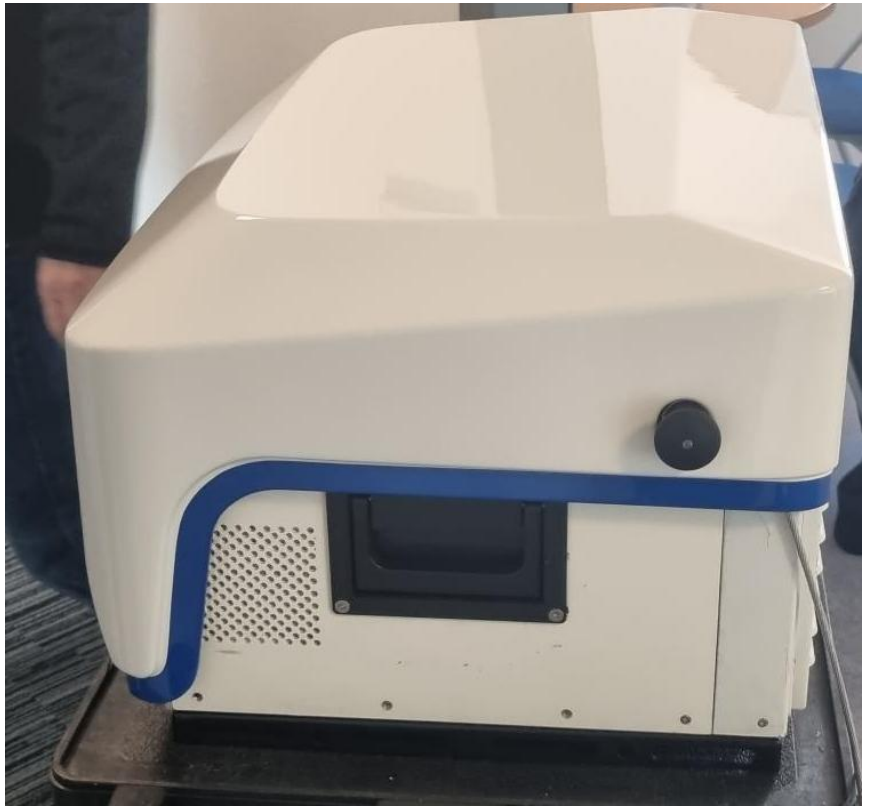
# Flexibility: Towbar, Trunk, partly on Towbar in Trunk







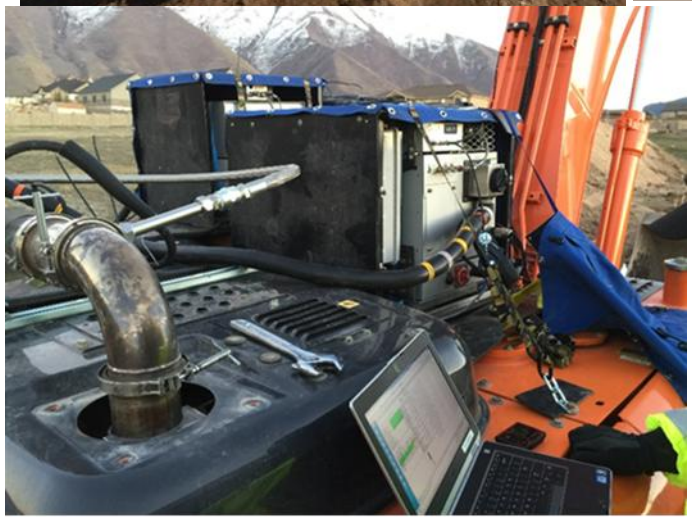

# Some Pictures..

# Some Pictures


# Installation Examples






# Thank You

# AVL Brake Emission Testing Solution

## AVL Aerosol & Gas Measurement Solution

Painsi, Alexander

# Agenda

**Introduction**

**Global Technical Regulation**

**AVL Brake Emission Testing Solution**

**Tire Wear Measurement**

# Introduction

**Alexander Painsi**
**Senior Business Development Manager**

Aerosol & Gas Measurement

alexander.painsi@avl.com

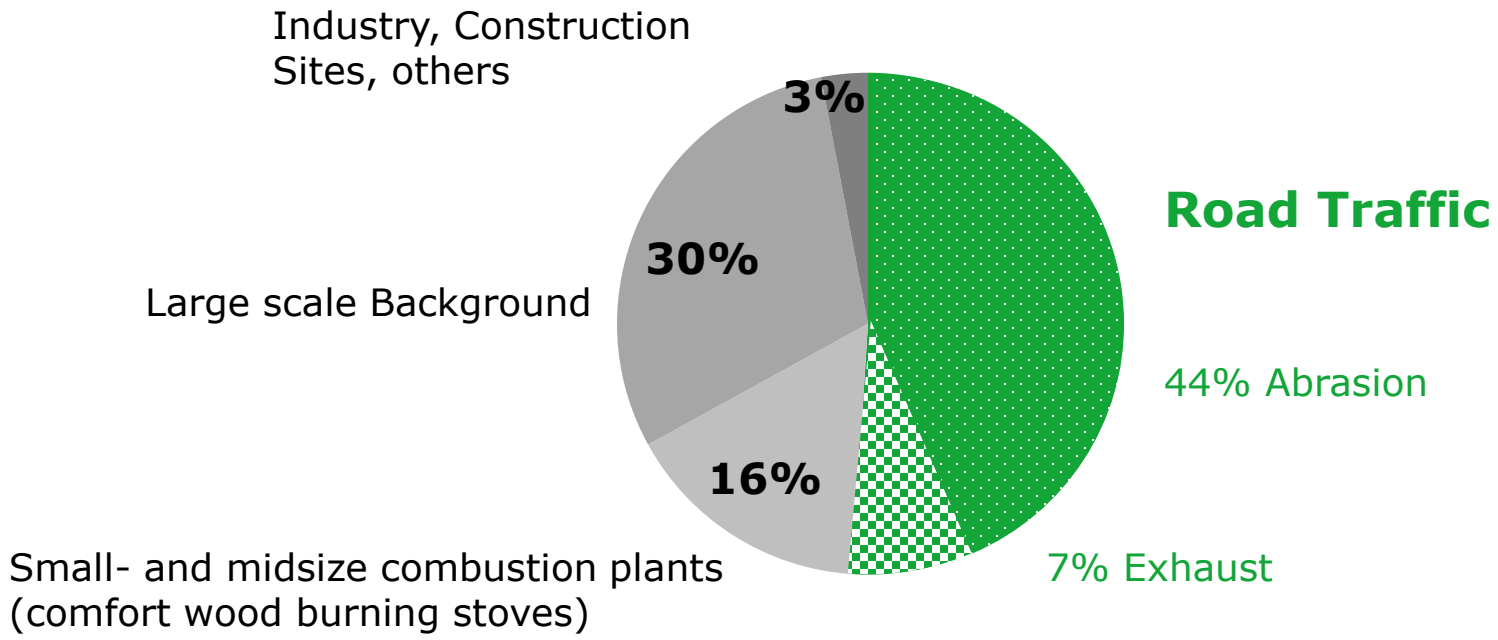
Over 22 years of engine testing experience in different global positions.

- Development Engineer
- Technical Trainer
- Product Manager
- Senior business development manager for Aerosol & Gas measurement at AVL.

Work focus: Particle and RDE measurement for all areas (LD,HD,NRMM)

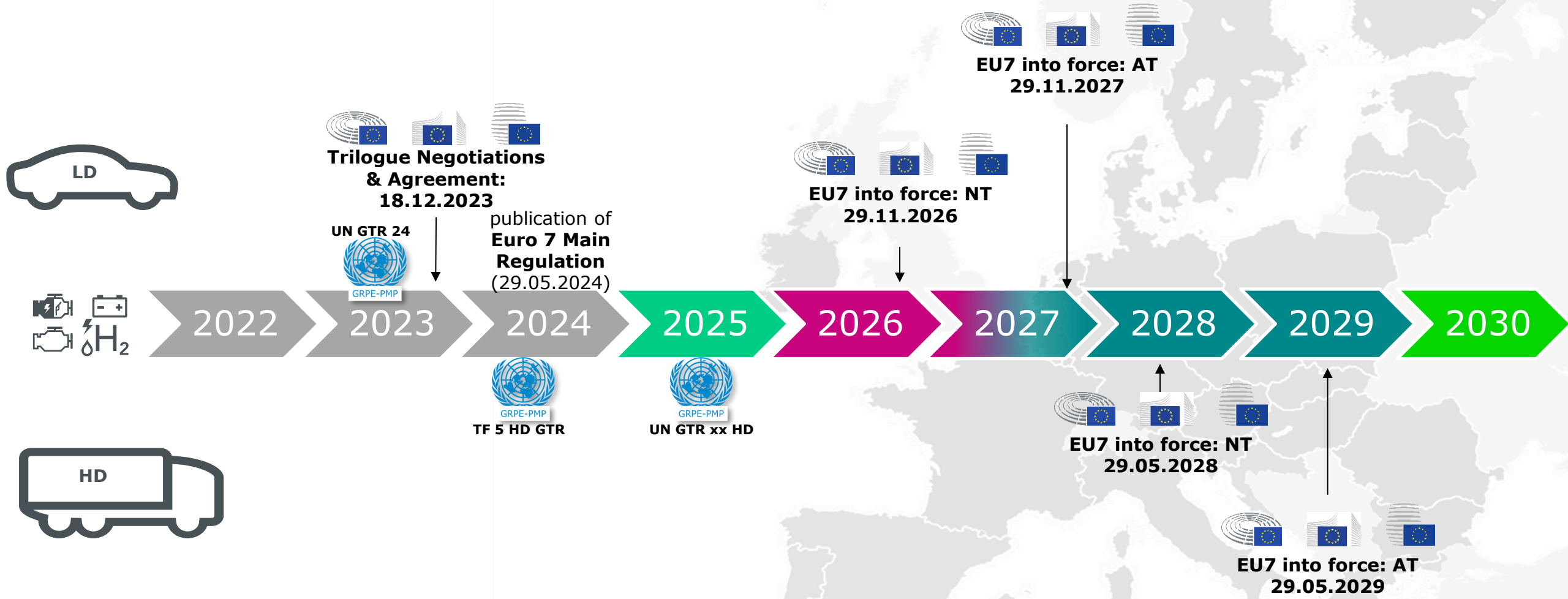
# Particulate Sources

## PM10 Sources and Distribution Neckartor (Stuttgart)




Source: LUBW, www.feinstaubalarm.stuttgart.de

# Way to Euro 7
## Actual Status




COM…European Comission , Council…European Council , EP...European Parliament

LD….Light Duty Vehicles; HD…Heavy Duty Vehicles; NT….New Types, AT…All Types; UN GTR…United Nations Global Technical Regulation

Status: 20.12.2023

# United Nations
# Global Technical Regulation (UN GTR)

# Way to United Nations Global Technical Regulation (UN GTR)

Particle Measurement Program (PMP)

GRPE-PMP

United Nations

Other Members (Subtotal)

Audi, BMW, Ford, GM, Stellantis, HORIBA, AVL, LINK, TSI, DEKATI, ITT, brembo, Continental, TMD FRICTION, FEDERAL-MOGUL MOTORPARTS, TECHNISCHE UNIVERSITÄT ILMENAU

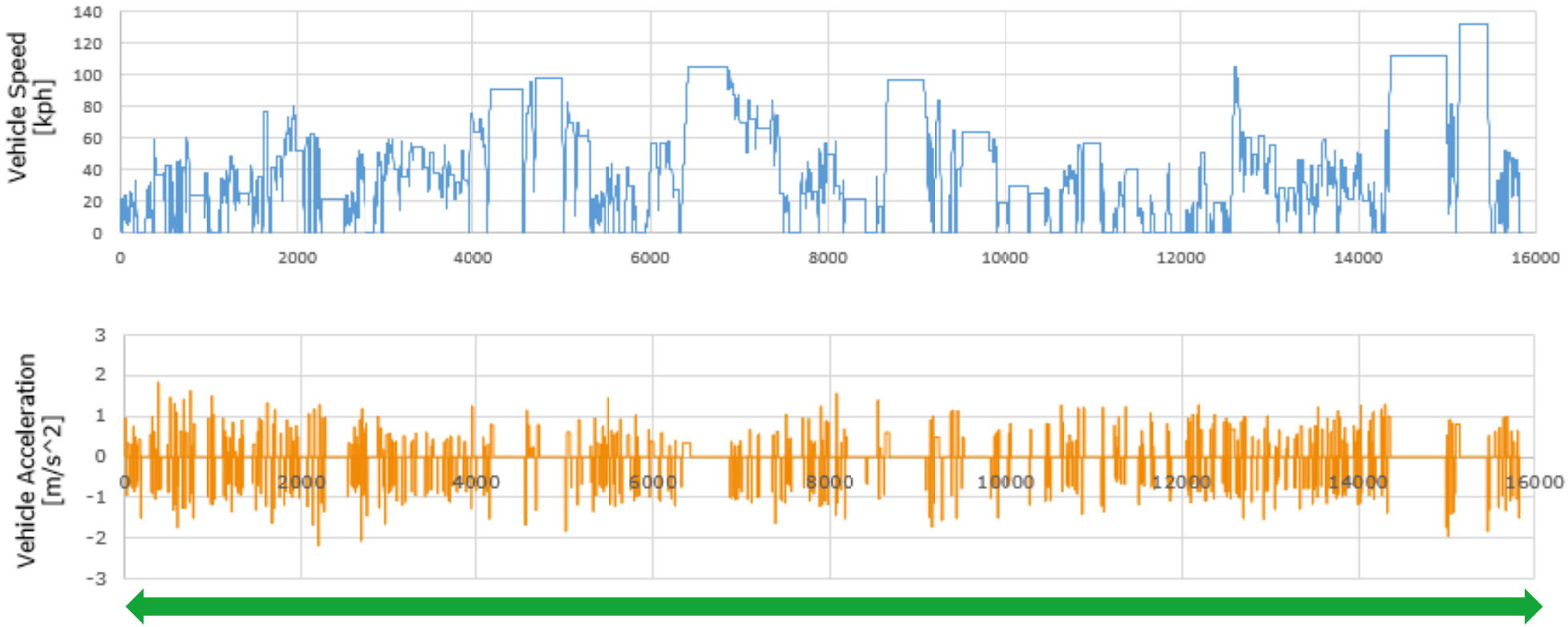
**Organized in Task Forces:**

- **TF1:** Definition of Brake Cycle
- **TF2:** Definition of Measurement Methodology
- **TF3:** Round – Robin Tests
- **TF4:** Influence of Recuperation

- **Brake Cycle** ➔ **WLTP Brake & Test-Protocol WLTP**
- **Test Environment** ➔ **Tetsbed & System Layout**
- **Meas. Methotology** ➔ **PM & PN**
- **Influence of EV** ➔ **Consideration of Rekuperation**

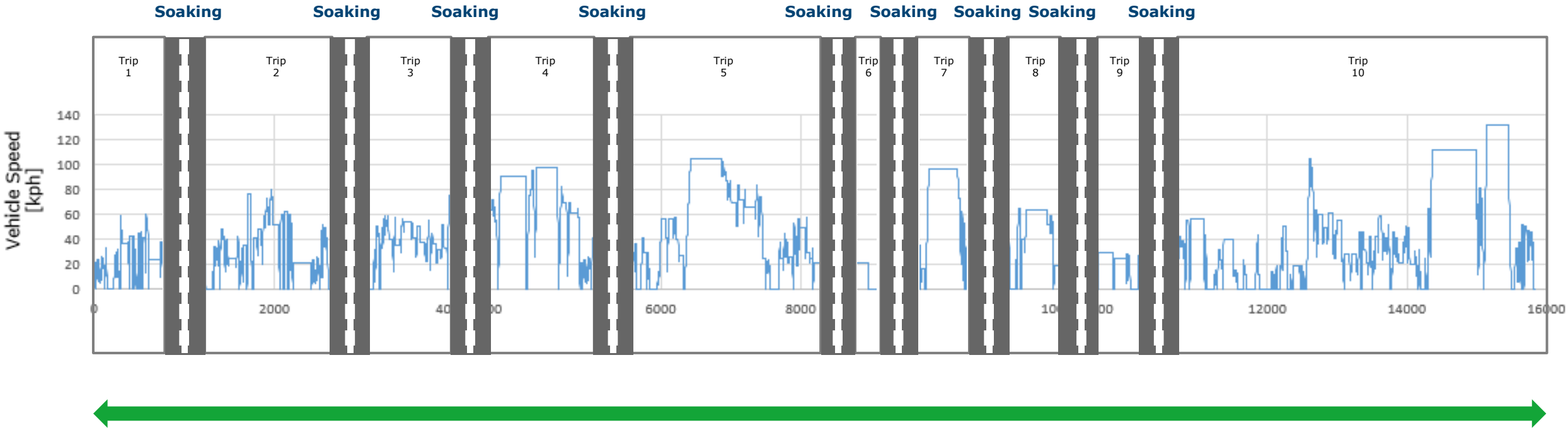
Sources Pictures: //www.audi.com; //www.bmw.com; //www.ford.com; //www.gm.com; //www.stellantis.com; //www.horiba.com; //www.link.com; //www.tsi.com; //www.dekati.com; //www.itt.com; //www.brembo.com; //www.continental.com; //www.tmdfriction.com; //www.mat-gmbh.de; //www.tu-ilmenau.de

# WLTP – BRAKE



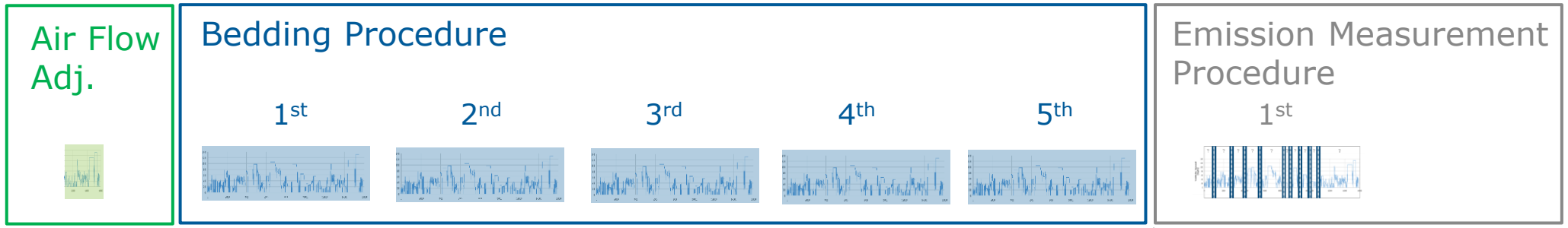

- 16.000 sec. = 4,5h
- 192 km
- 303 braking events

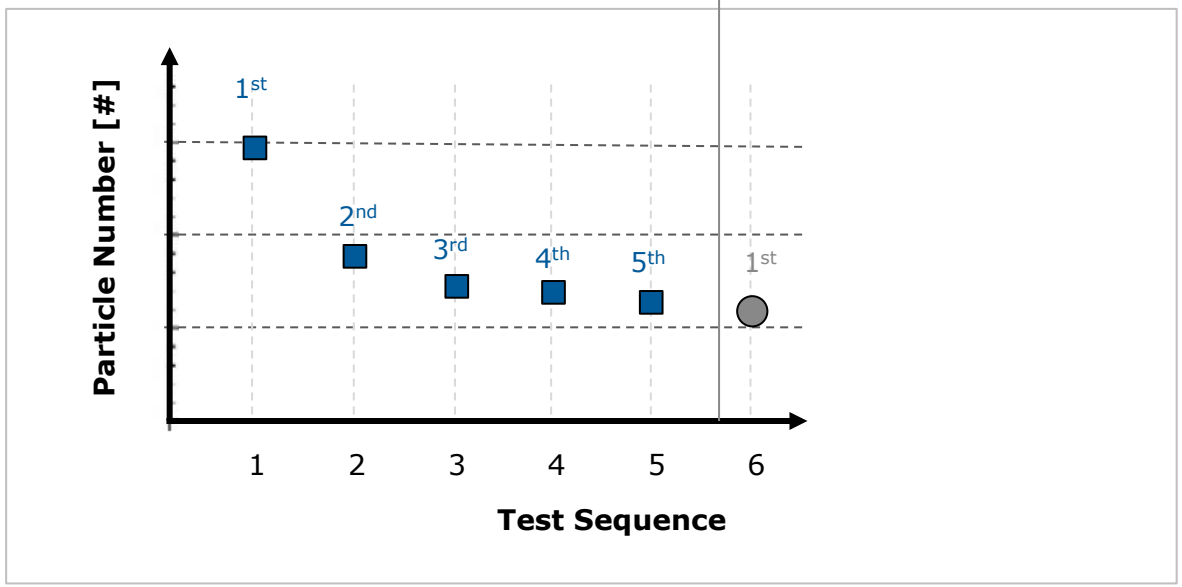
# WLTP – BRAKE




Cycle is split in 10 sections with intermediate cooling between (40°C) which leads to extended testing time.

# Way to United Nations Global Technical Regulation
# UN GTR – WLTP Brake Emission Procedure



# Way to United Nations Global Technical Regulation Definition of Measurement Methodology

## Particulate Mass – PM

- Critical property with long-established correlation with adverse health effects (HEI, WHO).
- Key concern given the high emission levels (both $PM_{2.5}$ and $PM_{10}$) relative to exhaust and their relevance even for electric vehicles.
- Several studies verified the feasibility of representative measurements of $PM_{10}$.

➔ Gravimetric quantification of both $PM_{2.5}$ and $PM_{10}$ is required.

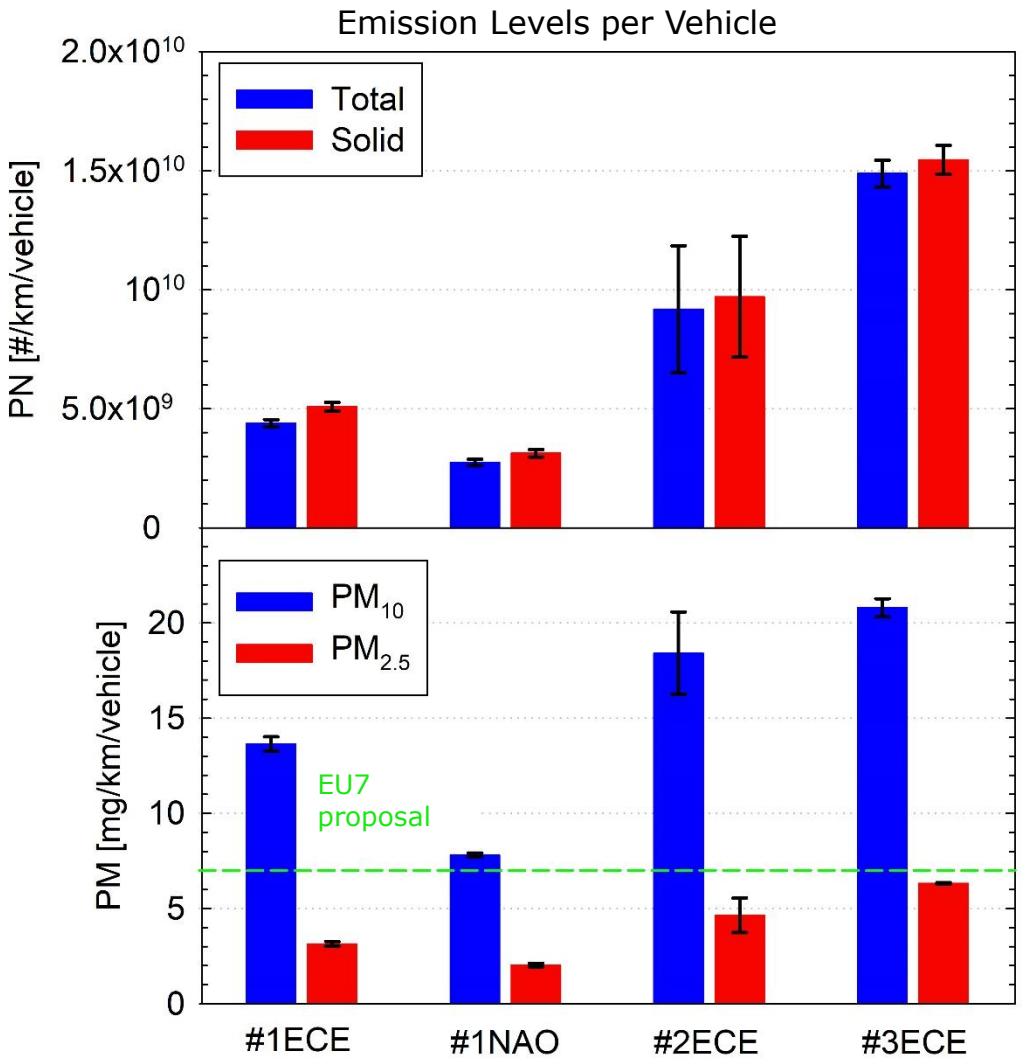
## Particulte Number – PN

- Strong interest in PN measurements mainly due to concerns about elevated emission of volatile nanoparticles

➔ Solid PN & Total PN measurement necessary

  - Methodology largely based on exhaust
  - Focus on 10 nm – 2.5 µm range

# AVL Brake Emission Measurement Solution
# Measured BW emission levels



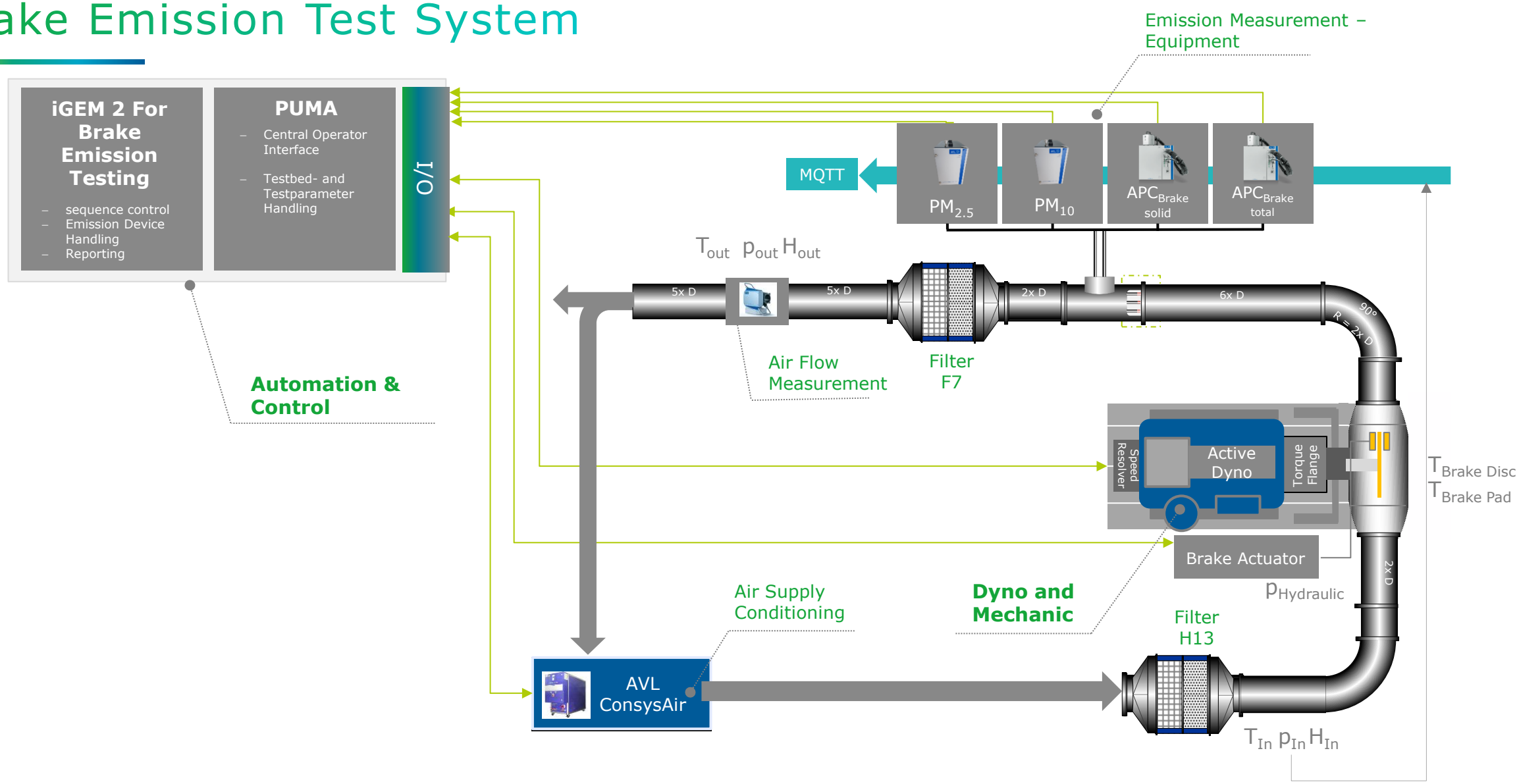

- BW emissions from three reference brake systems (#1 to #3; all front brakes) were measured
- Emission Results:
  - Brake System #1 with NAO pads NAO
    → close to EU7 Proposal*
  - Brake Systems with ECE Pads ECE
    → clearly above EU7 Proposal*
  - PN solid vs. total … for the WLTP-Brake Cyle(!)
    → close correlation observed at AVL Testbed

**Conclusion:**

- Technical risk for OEMs to achieve limits OEMs
- High Testing need → gain knowledge about emission levels of brake systems

* Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL 10th of November 2022; EU7 Proposal*: $PM_{10}$: 7mg/km

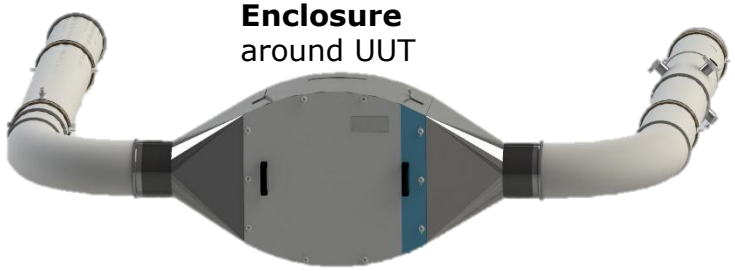
# Brake Emission Test System



# AVL Brake Emission Measurement Solution Development according GTR Requirements

GRPE-PMP

## BW – Sampling System



**Enclosure**
around UUT

## Particulate Mass – PM

**Gravimetric PM:**
<10µm
<2.5 µm

PM Sampler
PM10

PM Sampler
PM2.5

## Particle Number – PN

**CPC-based PN:**
>10 nm

APC xBrake
For Total PN
(Solid + Volatile PN)

APC xBrake
For Solid PN

Outlook: Automatic Filter Changer available by 2024

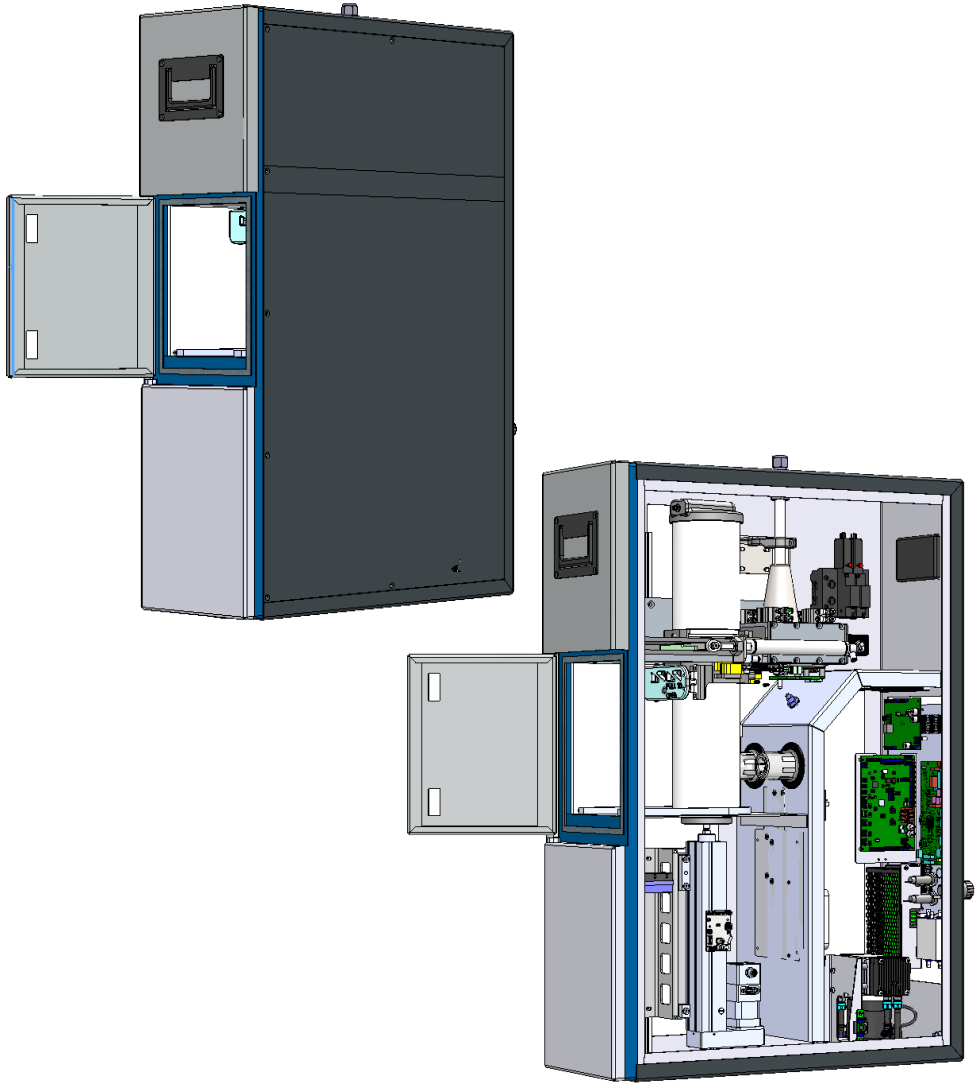
# AVL Brake Emission Testing Solution

# AVL PM Sampler

**AVL PM Sampler PM10 & PM2.5**

- GTR compliant particulate mass measurement device
- Particulate Mass Measurement:
  - PM10 & PM2.5
- Cyclones for PM10 & PM2.5 included
- PM Filter Size 47mm
- Flow Rate: 3 – 17 ln/min
  - Accuracy: <±2%
- Real-time compensation for pressure, temperature and humidity

# AVL Brake Emission PM Sampler xChange



AVL Brake Emission PM Sampler xChange

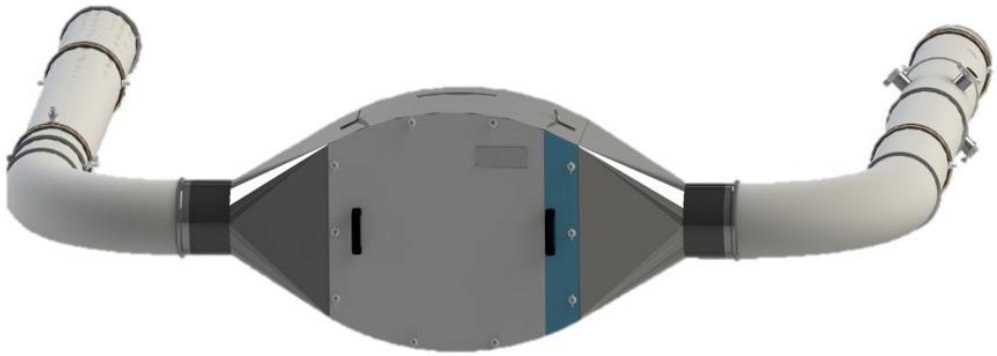
- Filter changer meets current GTR requirements (GTR status 13.01.2023)
  - Sample gas path identical to current PM sampler → no flow split!
- maximum flexibility and efficiency
  - Test field utilization 24/7
  - automated loading of up to 16 filters (e.g. overnight or over the weekend)
- PM - measurement with up to max. 16 filters per size (2.5/10µm)
  - Optimized with regard to particle losses:
- Optional: Filter identification via RFID → Compatibility with weighing robot

# AVL APC xBrake SPN & TPN


**AVL APC xBrake SPN & TPN**

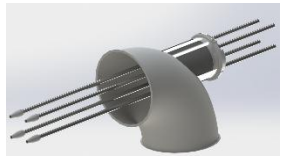
- Core Sensor – AVL CPC 10nm
- Lower particle size limit: 10nm
- Measuring range:
  - 0 - 30,000 p/cm³ (single count mode)
- PCRF Tot: 20, 100, 1000
- Flow rate: 8 l/min
- Total Particle Number (TPN):
  - No Catalytic Stripper
  - No heating of sample gas
  - Active cooling of PND1

# AVL Brake Emission Sampling System



**AVL Brake Emission Sampling System**

- GTR compliant Brake Emission Sampling System GTR
- Inner Diameter 200mm
- Flow Rate: 300 – 1500 $m^3/h$
  - Flow Straightener in Enclosure implemented
- Sampling: modular design
  - AVL recommendation: Straight Sampling Probes configurations
  - Other probe (90° bend) available (e.g. Flange solution)



# AVL Test System

## Active Dyno

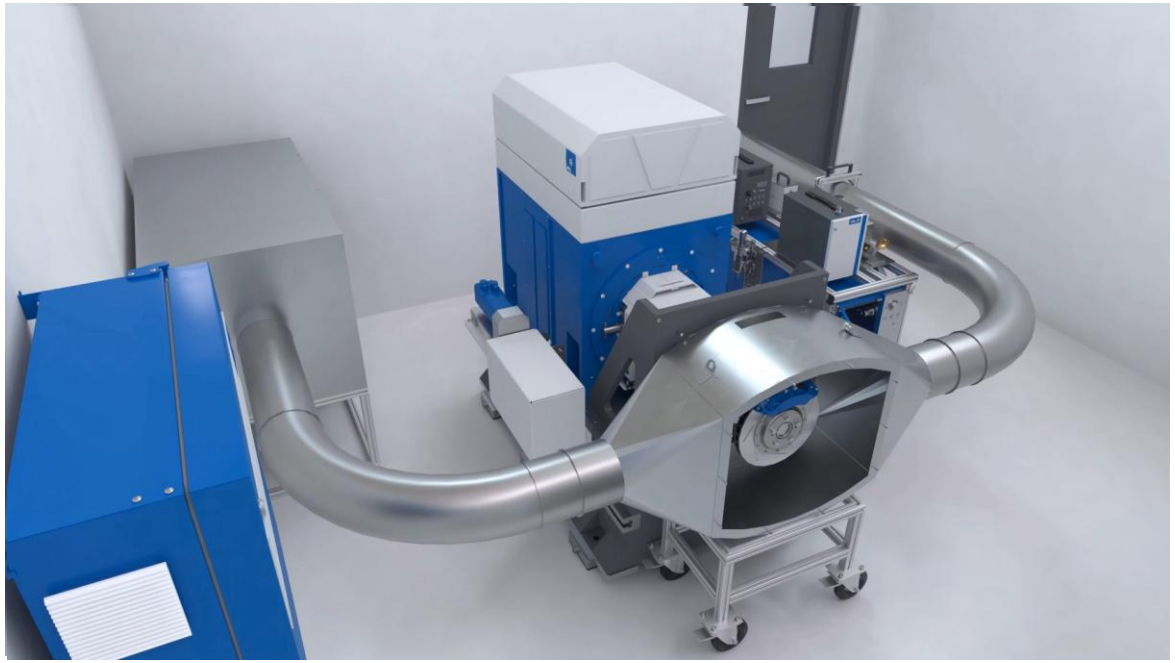
AVL provides test system concept with active dynos which enables to transfer Co-Simulation to brake emission testing.

## Compact Footprint

AVL concepts follows min. footprint which allows to max. testing capability by limited space requirements.

## Integrated Solution

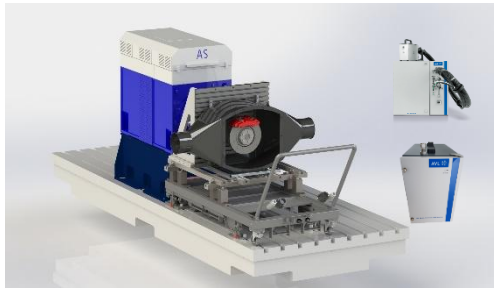
Comprehensive integrated solution for test- and emission measurement equipment.



# Test System Layout Examples

# Cover Additional Testing Effort

## Opt. A



AVL quote:
Brake Wear Emission Kit
- AVL Engine Testbeds
- Non AVL Testbeds

Existing:
Engine Test Equipment

Existing:
Testbed Infrastructure

## Opt. B

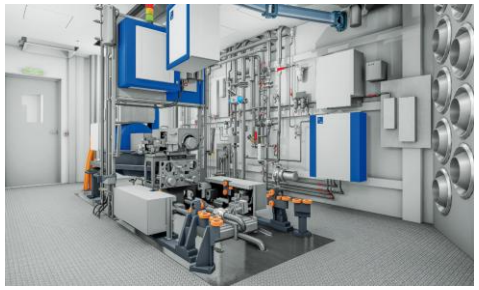
AVL quote:
Brake Wear Emission Kit

AVL quote:
Dyno + Test Equipment

Existing:
Testbed Infrastructure

Upgrade of Existing
Testbed Infrastructure

## Opt. C



AVL quote:
Brake Wear Emission Kit

AVL quote:
Dyno + Test Equipment

AVL quote:
Testbed Infrastructure

Brake Emission Test System
incl. Containerized Facility

## Opt. D

AVL quote:
Brake Wear Emission
Testing As a Service

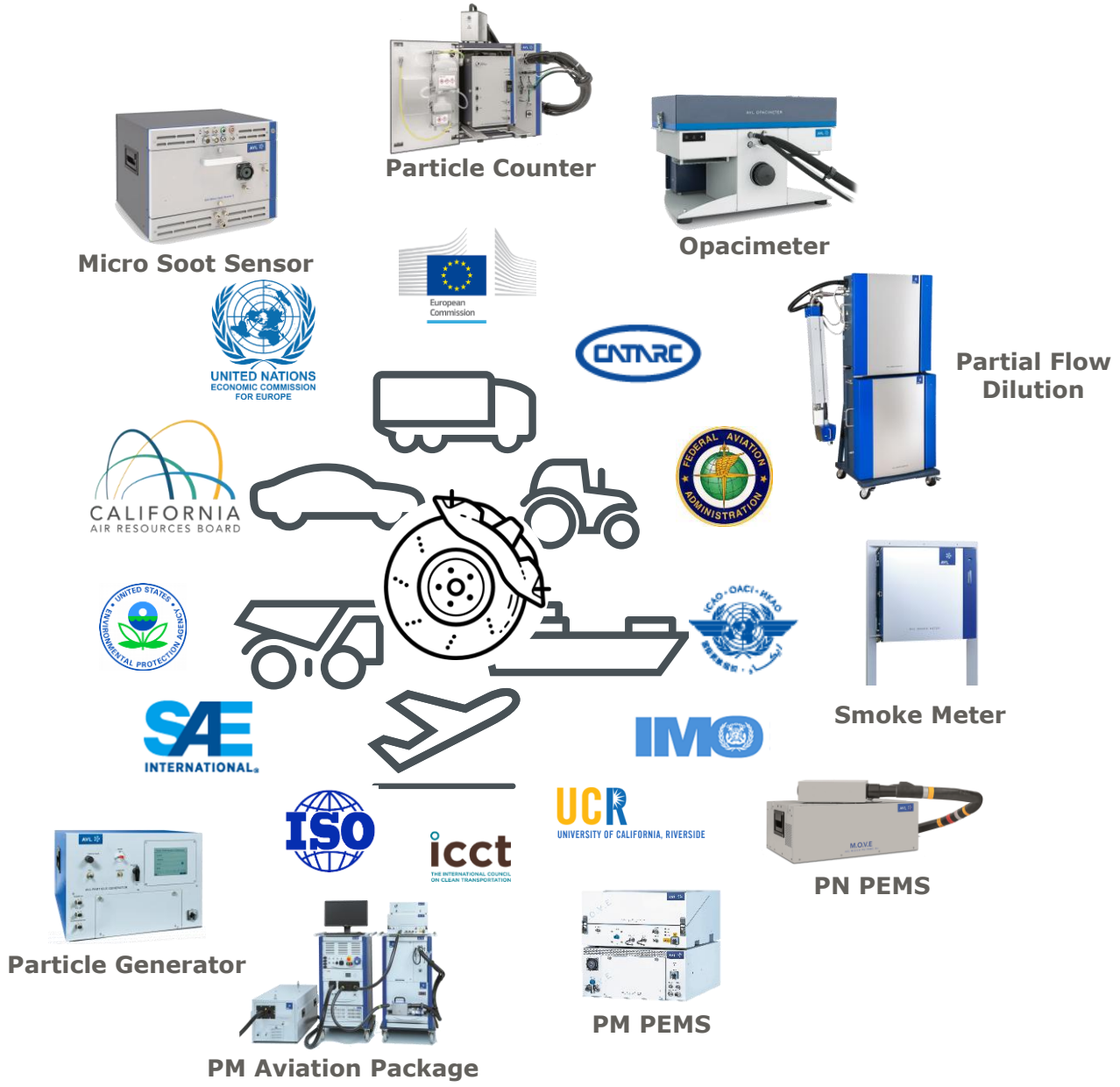
AVL quote:
Brake Engineering
As a Service

Brake Emission Testing &
Engineering

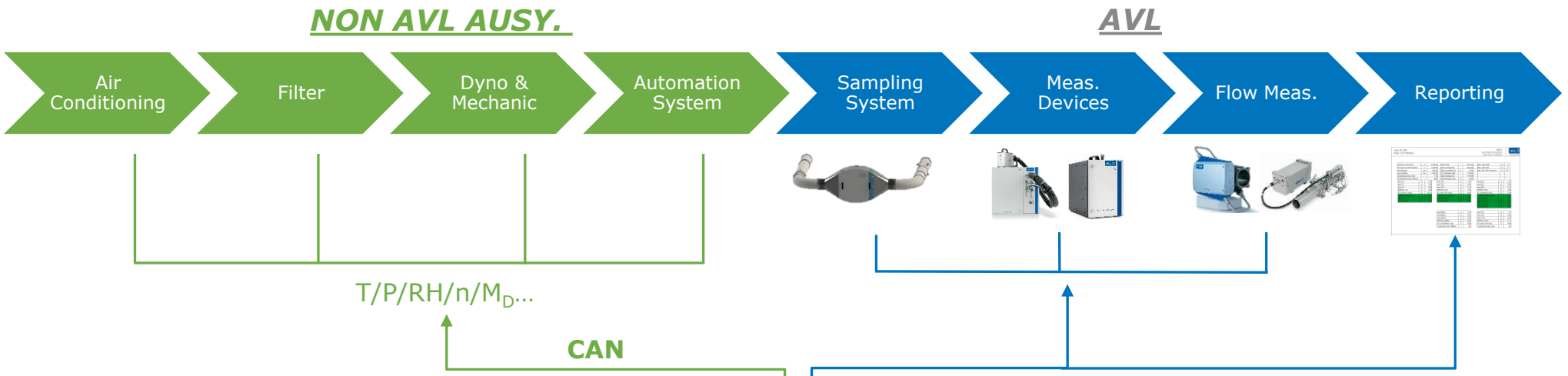
# AVL Particle Measurement

**AVL**

- Market leader in particulate measurement
  - >50 years experience
  - > 17.000 installed particulate measurement devices
- Complete product portfolio for Brake emissions testing
- Strong application knowhow on brake emissions
- AVL has an active role in GTR 24 (Brake Emission) discussions and best-in-class measurement results.



# Inputs - Responsibilities

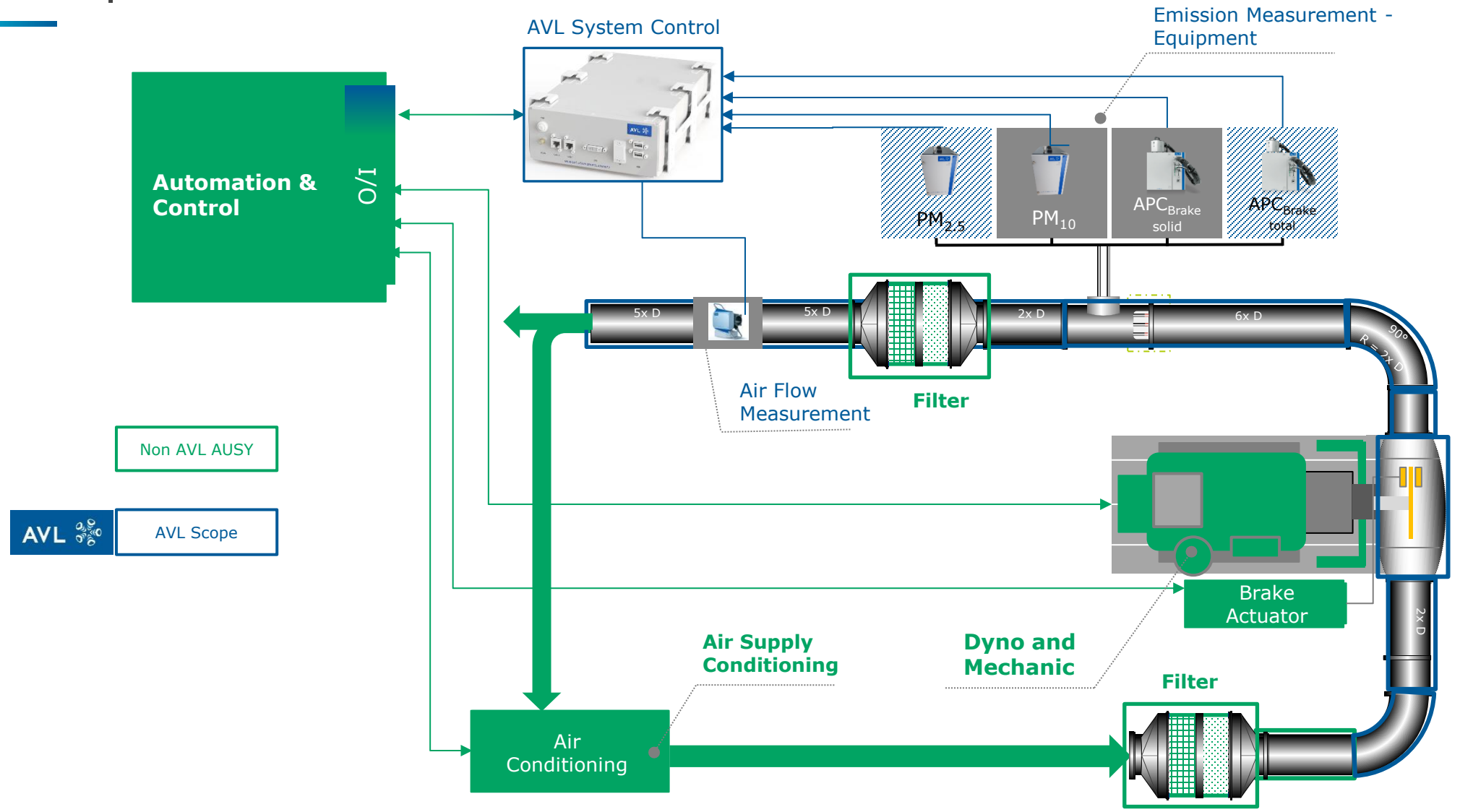



- Dyno- and air conditioning-Control
- Test cycle
- Deliver to AVL the relevant channels/data for post-processing
- Piping adaptions for the enclosure
- Adaption of the mechanical interface to the enclosure
- Etc.

- Device handling
- Test guidance Pre/Post routines
- Time synchronisation
- Data storage

- Provide key elements to ensure accurate and reliable brake emissions measurement (Measurement devices + Enclosure + Sampling probes + flow measurement + Post-processing)
- Automation for Emissions Devices (pre/main/post)
- Emissions data recording & relevant parameters from the testbed
- Data post-processing (Concerto)

# Inputs/Responsibilities



# Outlook & Conclusion

# Brake Wear - Real Driving Emissions (RDE) Measurements

- Investigating the effects of different driving characteristics and ambient conditions
- Real world temperature and emission behaviour
- Geographically varying emissions – influence of descents
- Fill knowledge gaps – regenerative braking
- Driver for legislation

Starting point for legislation

**Complexity**

low ← high

**Repeatability**

high ← low

**Correlation to real world emissions**

weak → strong

Target

# Brake Wear - Real Driving Emissions (RDE) Measurements



# Conclusion

- Non-Exhaust Emissions → **Introduction with EU7** (Brake Emission & Tyre Abrasion)
- Establishment of a **new and complex measurement method**
- **AVL** supports with state-of-the-art **instrumentation and methodology**
- **RDE** approach for Brake Emissions → Announcement already in EU7
- **Further cooperative research efforts needed** (on Brake & Tyre Abrasion/Emission)

# AVL References

- CATARC
- VETC
- IAV
- AUDI
- DAIMLER
- BMW
- BREMBO
- IDIADA
- TecSA
- JAGUAR LANDROVER



厦门环境保护机动车污染控制技术中心
Xiamen Environment Protection Vehicle Emission Control Technology Center


Mercedes-Benz

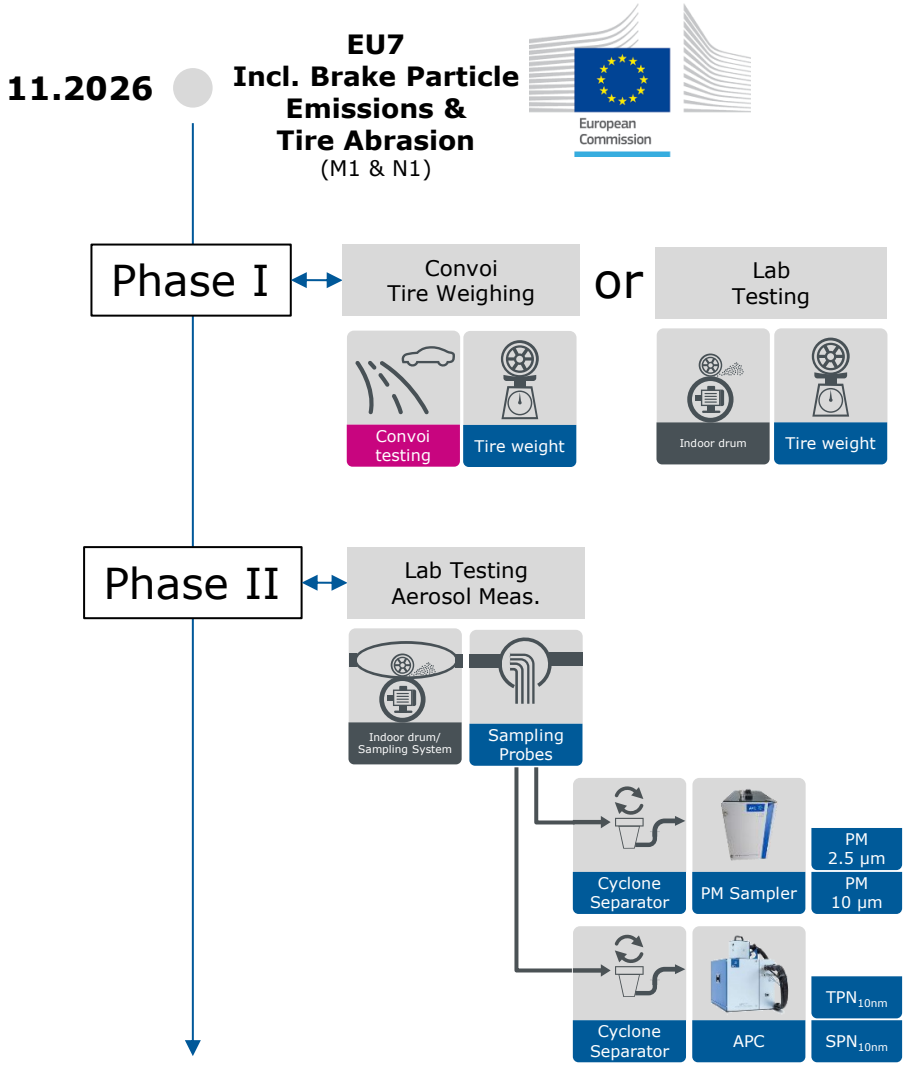




# From Tire Abrasion to Tire Emission
# The AVL View

Painsi, Alexander

# AVL view on future of EU7 – From Tire Abrasion to Tire Emission




*Publication of EU7 Main regulation; 8th of May 2024

## AVL view:

- EU7 implementation with convoy testing or Lab testing drum method (Nov. 2026) --> Phase I
  - \+ well known method
  - \+ fast implementation possible
  - \- impact of environmental conditions and road surface
  - \- Poor Repeatability
  - \- Huge testing amount → consumes a lot of testing capacity

- Correlation between convoy testing and lab testing (already discussed in PMP) to be demonstrated
  - \+ Lab testing ensures better repeatability
  - \+ stable environmental conditions
  - \+ fixed and comparable drum surface
  - \+ high repeatability
  - \- high acquisition costs

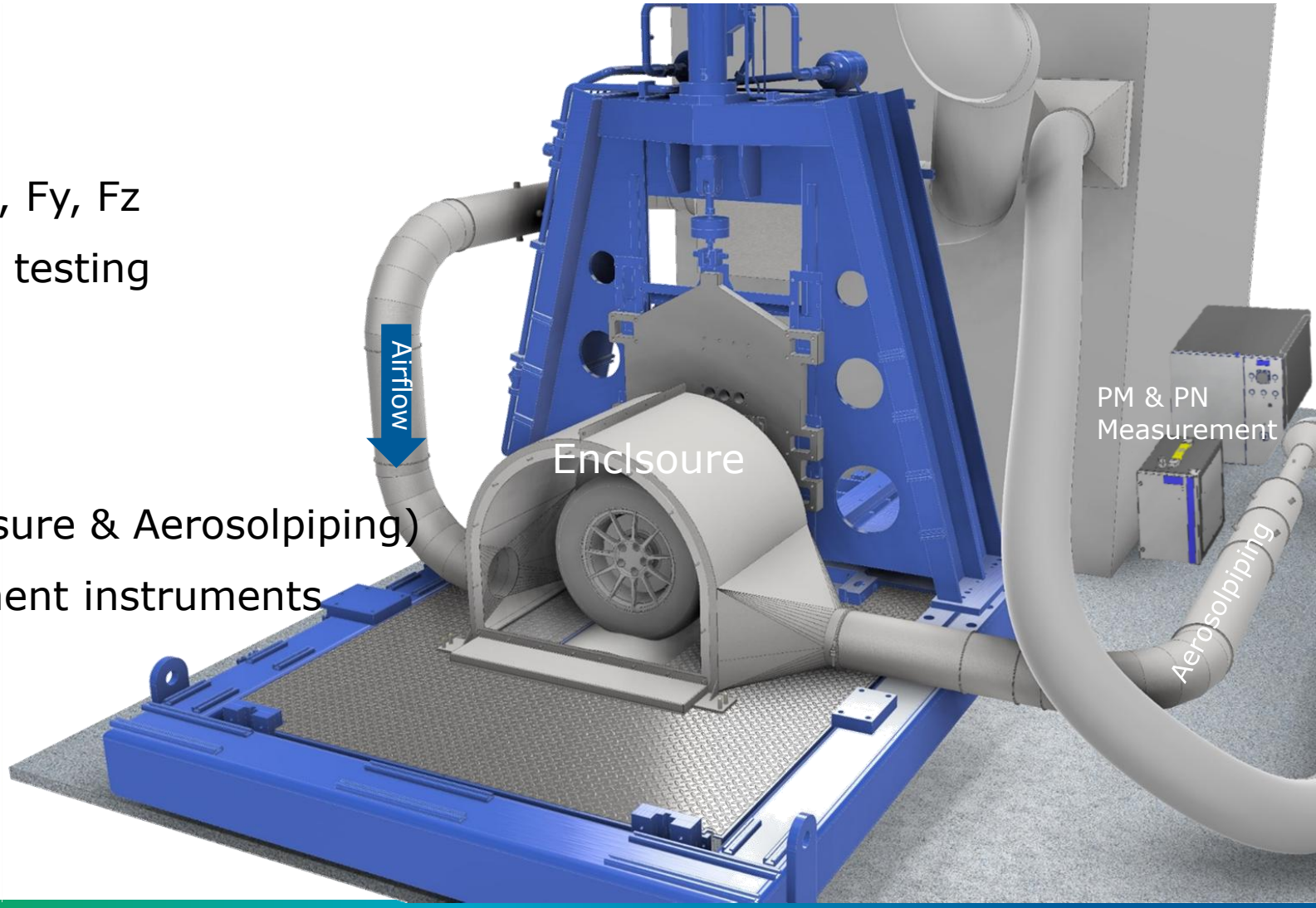
# From Tire Testbed to Tire Emission

***Tire Testbed***

- Roating drum
- Steerabel wheel suspension – Fx, Fy, Fz
- Stable environment – repeatable testing

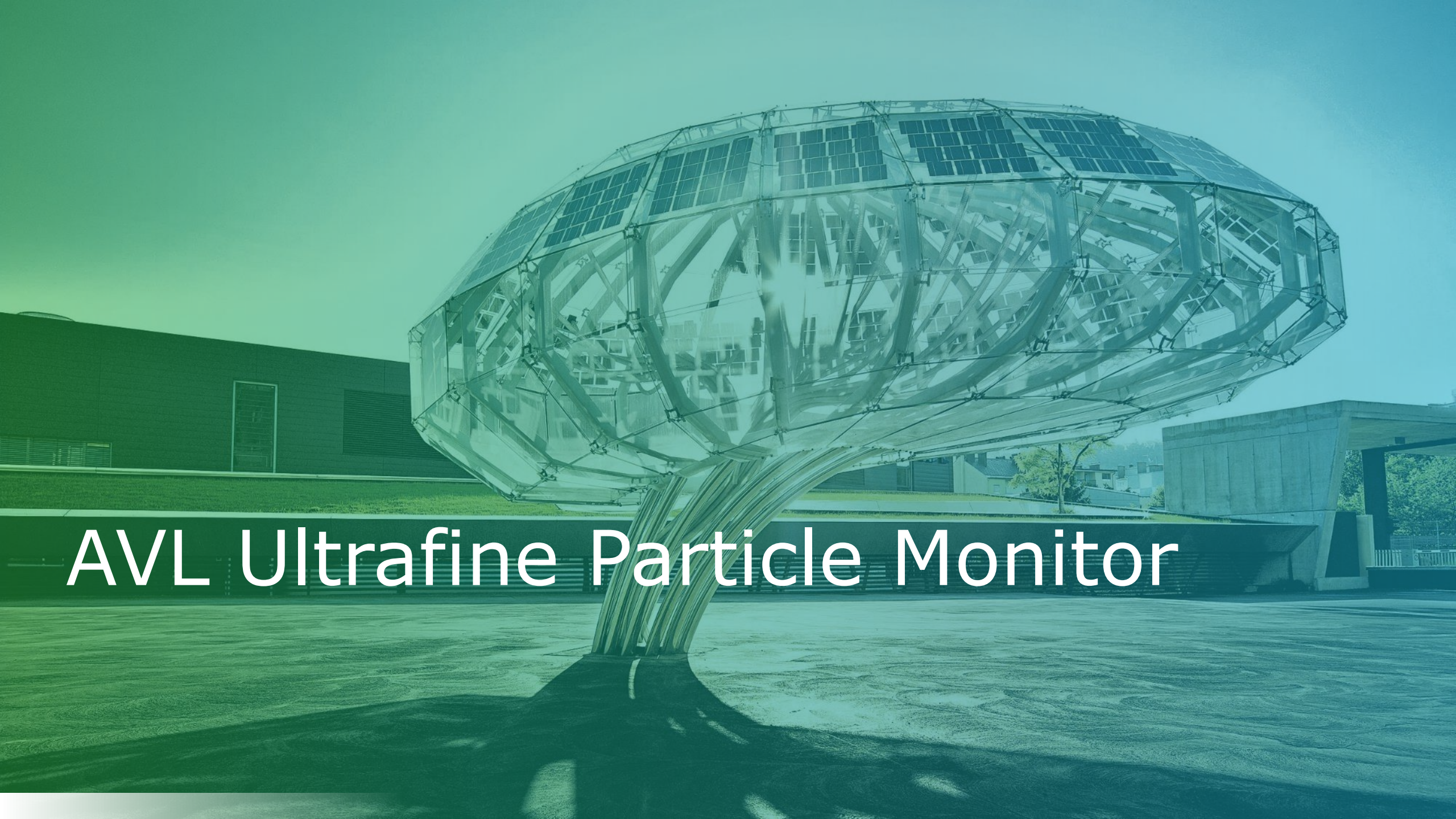
***Tire Emission Testbed***

- Conditioned cooling air
- Particle Sampling System (Enclosure & Aerosolpiping)
- Non Exhaust Emission Measurement instruments
  - PM
  - PN



# Thank you


www.avl.com



# AVL Ultrafine Particle Monitor

# AVL at a Glance

**1948**
Founded

**75**
Years of Experience

**26**
Countries Represented

**45**
Global Tech and Engineering Centers

**11,200**
Employees Worldwide

**68 %**
Engineers and Scientists

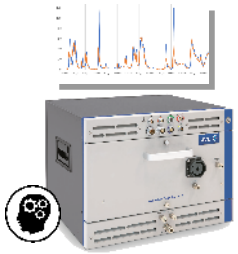
**11 %**
Of Turnover Invested in Inhouse R&D

**2,200**
Granted Patents in Force

# AVL Aerosol Measurement Technology Portfolio

## Reflectometry
**Smoke Meter**

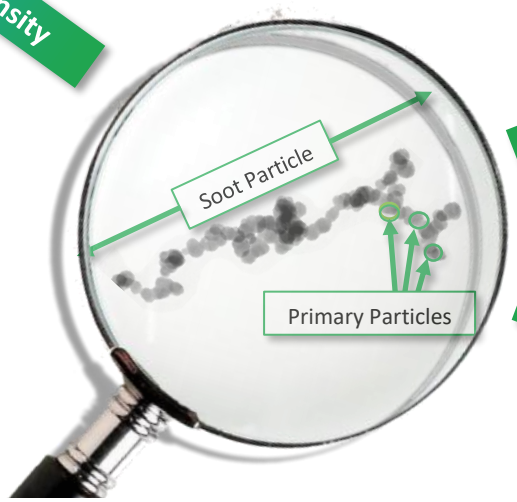
## Photo Acoustic Spectroscopy
**Micro Soot Sensor**



## Gravimetry & PFDS[1]
**Smart Sampler**

## Opacity
**Opacimeter**

Smoke Density




Particle Mass

## Gravimetry
**PM Sampler 2.5 and 10**

Particle Number

## Condensation Particle Counter
**AVL Particle Counter**

## Diffusion Flame Aerosol Generator
**AVL Particle Generator**

## Electronical Particle Counter
**MOVE PN PEMS**

Legislation required metric

Metric for research and development

[1.] Partial Flow Dilution System

# WHO Guidelines and the Introduction of Ultra Fine Particles

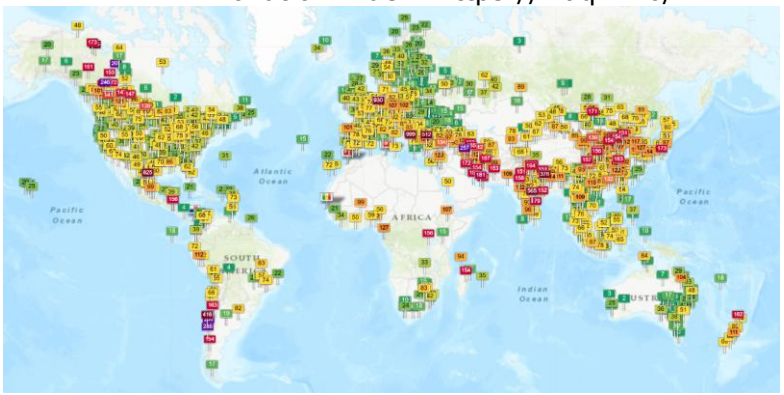
Public

# Global Guidelines and the Extension to Ultra Fine Particles


Air pollution caused 4.2 million premature deaths worldwide in 2019. (WHO, Link)

Governments globally search for countermeasures to reduce the economic burden caused by air pollution (OECD: 21 billion USD in 2015, LINK)

Air Pollution Index: https://waqi.info/

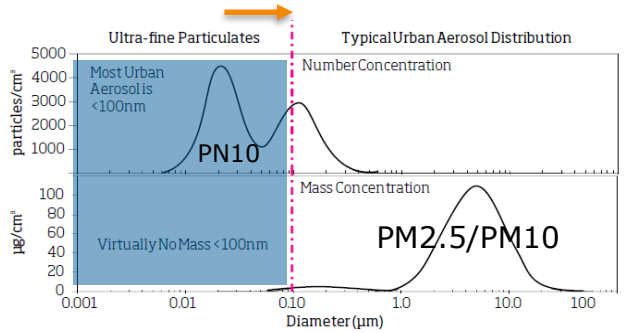


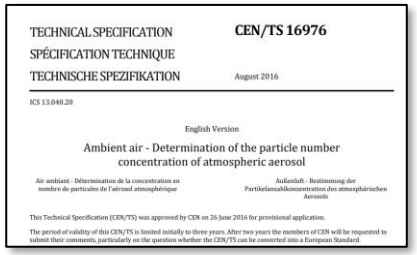

Source: web; 25.04.23;
WHO releases updated Global Air Quality Guidelines (rehva.eu)

Air Quality Guidelines (AQG) include + cont. limit refinement : $SO_2$, $NO_2$, $O_3$, CO, $PM_{10}$, $PM_{2.5}$

**U**ltra **F**ine **P**articles(UFP) = <100nm) for the 1st time introduced as "metric of interest"; recommendation to expand container equipment by UFP devices due to shortcomings of other methods

**B**lack **C**arbon (BC) and/or **E**lemental **C**arbon (EC) are also gaining in importance. These must be systematically measured in order to establish standards and derive limit values.





TECHNICAL SPECIFICATION
SPÉCIFICATION TECHNIQUE
TECHNISCHE SPEZIFIKATION
CEN/TS 16976
August 2016
ICS 13.040.20
English Version
Ambient air - Determination of the particle number concentration of atmospheric aerosol

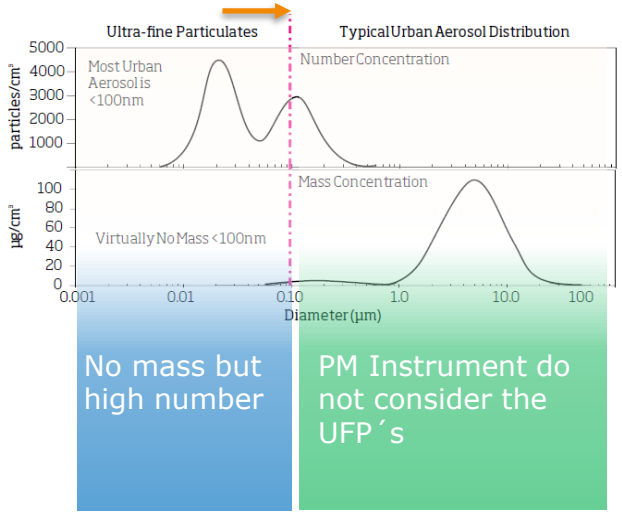
# Global Guidelines and the Extension to Ultra Fine Particles


- Air pollution to be on par with other major health risks: unhealthy diet, smoking tobacco
- Air pollution increases: morbidity and mortality from cardiovascular & respiratory disease and lung cancer
- Governments globally search for countermeasures to reduce the economic burden caused by air pollution


Source: web; 25.04.23;
[WHO releases updated Global Air Quality Guidelines (rehva.eu)]

- Air Quality Guidelines (AQG) include + cont. limit refinement : $SO_2$, $NO_2$, $O_3$, CO, $PM_{10}$, $PM_{2.5}$
- Traditional mass-based measurements are not fully representative: recommendation expand container equipment by UFP devices
- Harmonization of UFP measurement procedure : CEN 16976 – final version expected in 2024
- EN 16976 = technical specifications: e.g. measurement range, working principle, calibration procedure, …

*UFP … Ultra Fine Particles
<100 nm diameter




Source: Seinfeld, J.H.; Pandis, S.N., Atmospheric Chemistry and Physics; John Wiley and Sons, 1998

Peak performance condensation particle counting

# AVL UltraFine Particle Monitor

# Expertise

… in Particle Number Counting:

- 15+ years in the field of emission testing
- Installed Base: 1000+ units worldwide
- **Applications**: Automotive, Non-Road Mobile Machineries and Aviation
- Global Customer´s: OEM´s, Tier 1, Legal Authorities (e.g.JRC), Universities, Institutes
- Global available service and repair centers

# AVL Strengths & USPs


Laminar full flow butanol-based CPC: 100% AVL Technology

Fully compliant to the EN 16976 requirements and specifications

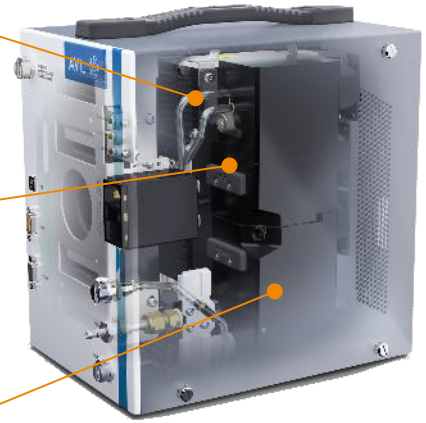
ACTRIS compliance approved

Automatic re-boot functionality ensures consistent data flow

Advanced drift detection leads to highest data quality

Very robust optical components tested with harshest aerosol compositions

Simplified component access for a straightforward maintenance, e.g. wick exchange



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ACTRIS compliance approved


ACTRiS CAIS-ECAC WCCAP World Calibration Centre for Aerosol Physics

**Performance Evaluation for ACTRIS Compatibility**

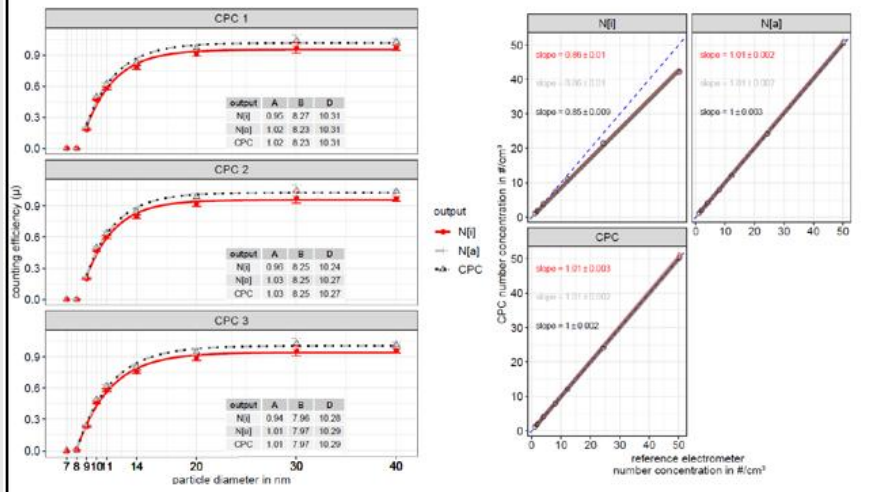
**of**

**Condensation Particle Counter**

| | |
|---|---|
| **Date of issue:** | **2024-01-29** |
| Date of Calibration | 2023-11-13 |
| Instrument Model | AVL Ultrafine Particle Monitor |
| Evaluating Unit | WCCAP, Leipzig, Germany |

**Performance Evaluation Results:**

| Performance Characteristics | Criteria | CPC1 | CPC2 | CPC3 | Unit |
|---|---|---|---|---|---|
| Detection efficiency at 40 ± 10 nm | ≥ 95% | 102 | 103 | 101 | % |
| Particle diameter where efficiency is ≥ 50% | $D_{50} = 10 \pm 1$ nm | 10.31 | 10.27 | 10.29 | nm |
| Detection efficiency at < 20 nm | ≥ 90% | 97 | 99 | 95 | % |
| Concentration response (linearity) | 100% ± 5% | 101 | 101 | 100 | % |



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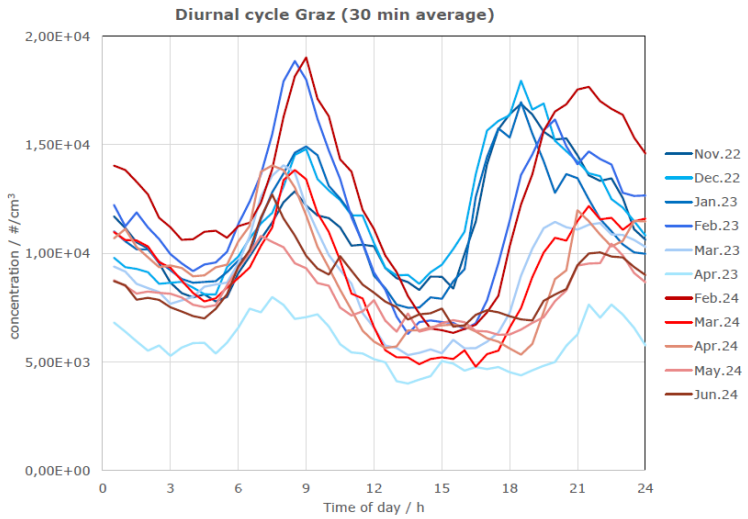
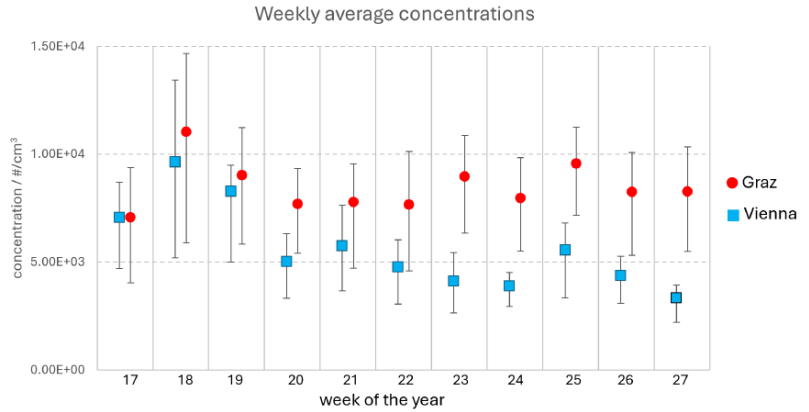



Monthly diurnal cycle from 2 individual 6 months campaigns (2022-2024)

## Device Experiences from multiple Measurement Campaign

- Focus: November - June
- Short-term max. UFP concentrations up to 1.5 E+05 #/cm³
- After the device installation only a re-filling of the operating fluid was necessary
- No error, no warnings – no other operator interaction was necessary
- Issues with competitive station CPC were identified with drift detection and underlined by manufacturer recalibration
- Currently multiple campaigns ongoing in Graz & Vienna.




10 week concentration statistics for Graz and Vienna


# Thank you

www.avl.com

**Johannes Murg**

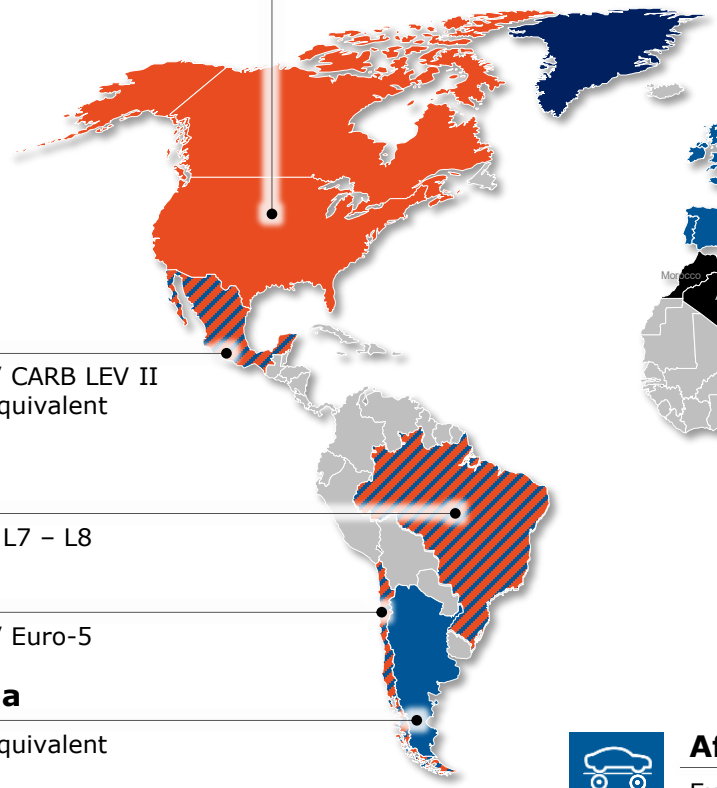
Group Product Manager
Aerosol and Gas Measurement
AVL List GmbH, Graz

johannes.murg@avl.com

# Light Duty CVS SL System for Future Legislation and beyond

Rongxin Gu
顾荣欣

# Legislation: Passenger cars 2018 – 2025 (expected)




**North America**
EPA Tier 3
CARB LEV III

**Europe**
Euro-6e

**Russia and Eurasia**
Euro-5 or equivalent

**South Korea**
EPA Tier-3 / Euro-6

**Japan**
PPNLT

**China**
China 6b

**India**
Bharat VI

**ASEA**
Euro-6 or prior
or equivalent

**Mexico**
EPA Tier 2 / CARB LEV II
Euro-4 or equivalent

**Brazil**
PROCONVE L7 – L8

**Chile**
EPA Tier 2 / Euro-5

**Argentina**
Euro-5 or equivalent

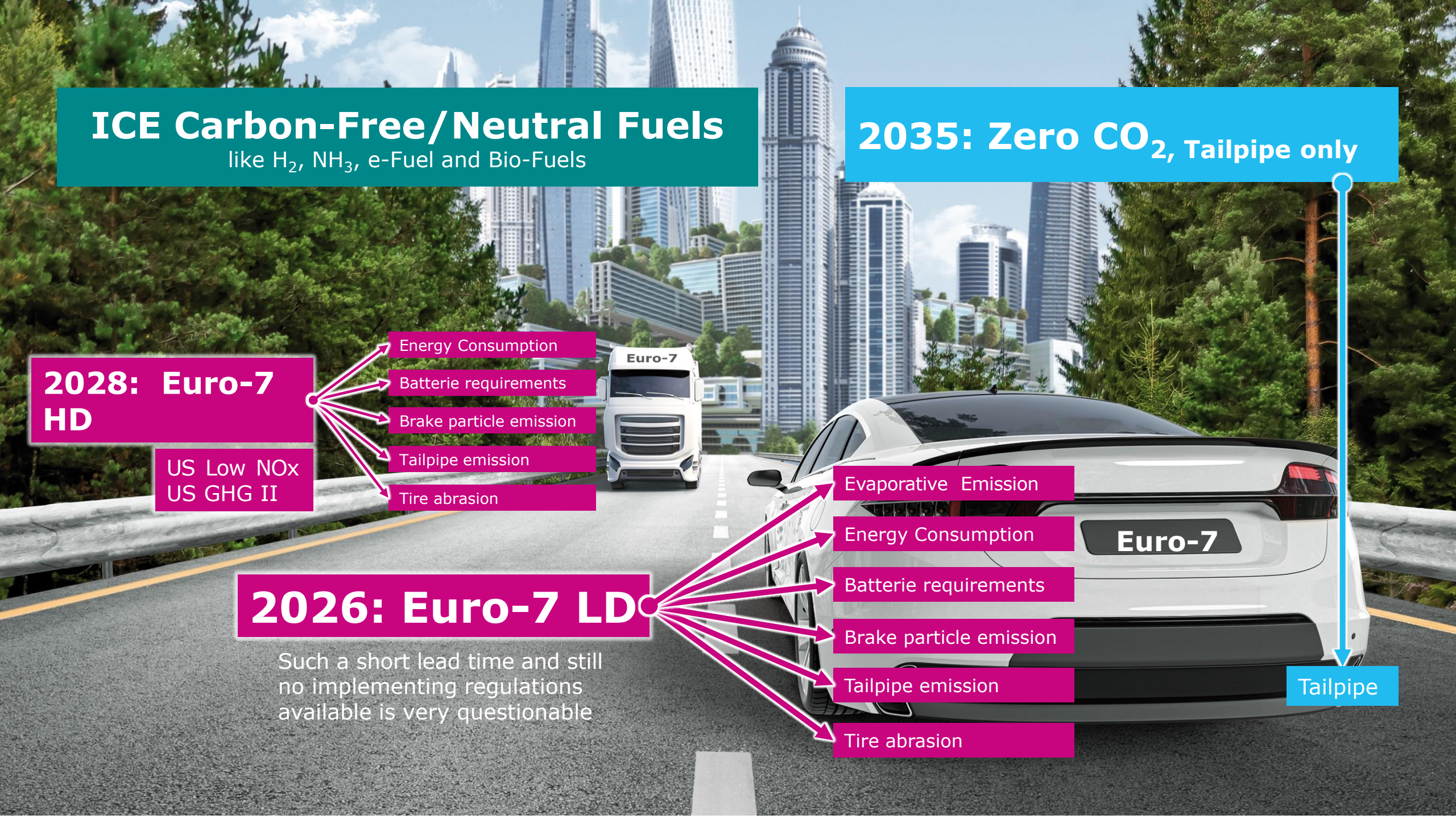
**Africa**
Euro-4, prior
or equivalent

**Iraq, Oman**
**Saudi Arabia**
Euro-4, prior
or equivalent

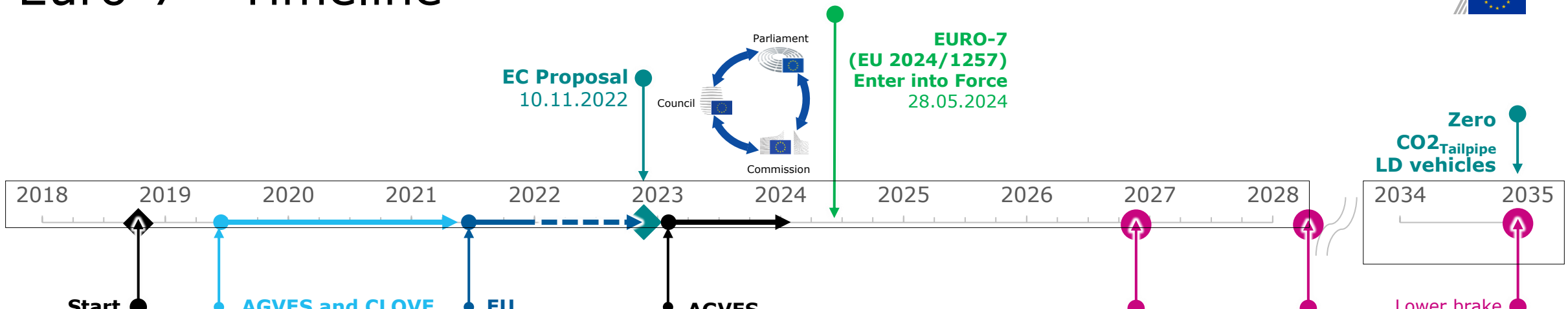
**Australia**
**New Zealand**
Euro-6 or equivalent

**Legend:**
US based legislation
US / UN-ECE legislation
UN-ECE based EU-0 ...4
UN-ECE based EU-5 ... 6c
UN-ECE based EU-6e
Laboratory tests
Real Driving Emissions
RDE Monitoring or defeat device chasing
EVAP

# Euro-7 Update


ICE Carbon-Free/Neutral Fuels
like $H_2$, $NH_3$, e-Fuel and Bio-Fuels
2035: Zero $CO_2$, Tailpipe only
2028: Euro-7 HD
US Low NOx
US GHG II
Energy Consumption
Batterie requirements
Brake particle emission
Tailpipe emission
Tire abrasion
Euro-7
2026: Euro-7 LD
Such a short lead time and still no implementing regulations available is very questionable
Evaporative Emission
Energy Consumption
Batterie requirements
Brake particle emission
Tailpipe emission
Tire abrasion
Euro-7
Tailpipe

# Euro-7 - Timeline




**Start**
24 Oct 18
Stakeholder event
Preparing for the future European Emission Standards
"**Post-Euro-6**"

**AGVES and CLOVE**
2 years, 12 meetings
90 Documents,
2125 pages

17.07.19 – 1st AGVES meeting
18.10.19 – 2nd AGVES meeting
04.02.20 - 3rd AGVES meeting
09.07.20 – 4th AGVES meeting
10.09.20 – 5th AGVES meeting
27.10.20 - 6th AGVES meeting
**1st CLOVE proposal**
16.11.20 – WS simplification
26.11.20 – 7th AGVES meeting
10.12.20 – PEMS Workshop
24.02.21 – 8th AGVES meeting
30.03.21 – InS electr. platform
08.04.21 – 9th AGVES meeting
27.04.21- 10th AGVES meeting
**2nd CLOVE proposal**

**EU Commission**
- Internal discussions and impact, assessments.
- Official EC proposal was continuously delayed.
- Published 10.11.2022

**AGVES**
- Implementing regulations
  Light-Duty Vehicles:
  21.06.23 $CO_2$
  20.07.23 Brake Systems
  **15.09.23 Implementing draft and OBM, Antitampering, Security**

  Heavy-Duty Vehicles:
  15.09.23 HDV Engines
  20.09.23 HDV $CO_2$
  **31.01.24 Implementing draft and OBM, Antitampering, Security**
- Meetings:
  30.11.22 ✓
  22.02.23 ✓
  15.03.23 ✓
  29.03.23 ✓
  ~~19.04.23~~ (Cancelled)
  07.06.23 ✓
  ~~05.07.23~~ (Cancelled)
  24.10.23

**Euro-7**
Light-Duty
(TA)
29.11.2026

**Euro-7**
Heavy-Duty
(TA)
29.05.2028

Lower brake wear limit
7 to 3 mg/km

**CLOVE = Consortium for Low Vehicle Emissions**

**AGVES** = **A**dvisory **G**roup **V**ehicle **E**mission **S**tandards

# Euro 7: Requirements

| Euro 7 | Light-Duty | Heavy-Duty |
|---|---|---|
| Implementation date | **Q4 2026 New types / Q4 2027 All vehicles** | **Q2 2028 New types / Q2 2029 All vehicles** |

Legend: Green text: new with Euro 7. Red crossed out text: difference to the EU Commission proposal from 2022

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| Tailpipe Emission | Limit | wie EU6 mg/km / #/km, ~~no emission budget~~ | | | | **-50%** of EU-VI mg/kWh / #/kWh, ~~no emission budget~~ | | | |
| | Fuel | separate Diesel and Gasoline, ~~no harmonization~~ | | | | - | | | |
| | Pollutants Gaseous | CO, NOx, THC, NOx+THC, NMHC, ~~$NH_3$~~ | | | | CO, NOx, NMOG, $CH_4$, **$NH_3$ as mass, $N_2O$,** HCHO will be reviewed 2027, ~~no Idle NOx~~ | | | |
| | Pollutants PM/PN | PM, **PN10** | | | | PM (only in WHTC/WHSC), **PN10** | | | |
| | based on | WLTP and RDE NOx and PN with CF (UNR-168) | | | | WHTC/WHSC, **RDE all except PM and higher limits** | | | |
| | RDE Temperature | (-7°C) | 0°C | +35°C | (+38°C) | - | -7°C | ~+35°C | - |
| | RDE Altitude | 700m extended 1,300m | | | | ~ 1,700 m (based on abs. pressure) | | | |
| | RDE Driving | Euro 6 limitations with CF, ~~wide open road~~ | | | | Euro VI limitations, 6% power threshold, ~~wide open road~~ | | | |

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| Non-Tailpipe emissions | **Brake wear** | **7mg/km and 3mg/km (PEV)<br>11mg/km and 5mg/km (PEV)** | | | | | | | |
| | **Tire micro-Plastic** | **Yes** | | | | **Yes** | | | |
| | EVAP | **1.5g** instead of 2.0g, ~~Re-Fueling test~~ | | | | no | | | |

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| $CO_2$, Energy consumption, e-Range | | Chassis dyno testbed based on WLTP | | | | Engine testbed and VECTO simulation | | | |

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| | **Tire micro-Plastic** | **Yes** | | | | **Yes** | | | |
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| **OBM (On Board Monitoring)** | | **NOx, PM**, ~~$NH_3$~~ | | | | **NOx, PM, $NH_3$** | | | |
| **Anti tampering** | | **Yes** | | | | **Yes** | | | |

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| **OBM (On Board Monitoring)** | | **NOx, PM**, ~~$NH_3$~~ | | | | **NOx, PM, $NH_3$** | | | |
| **Anti tampering** | | **Yes** | | | | **Yes** | | | |
| Durability-Emission and Durability battery and battery state of health | | **Yes** | | | | **Yes** | | | |

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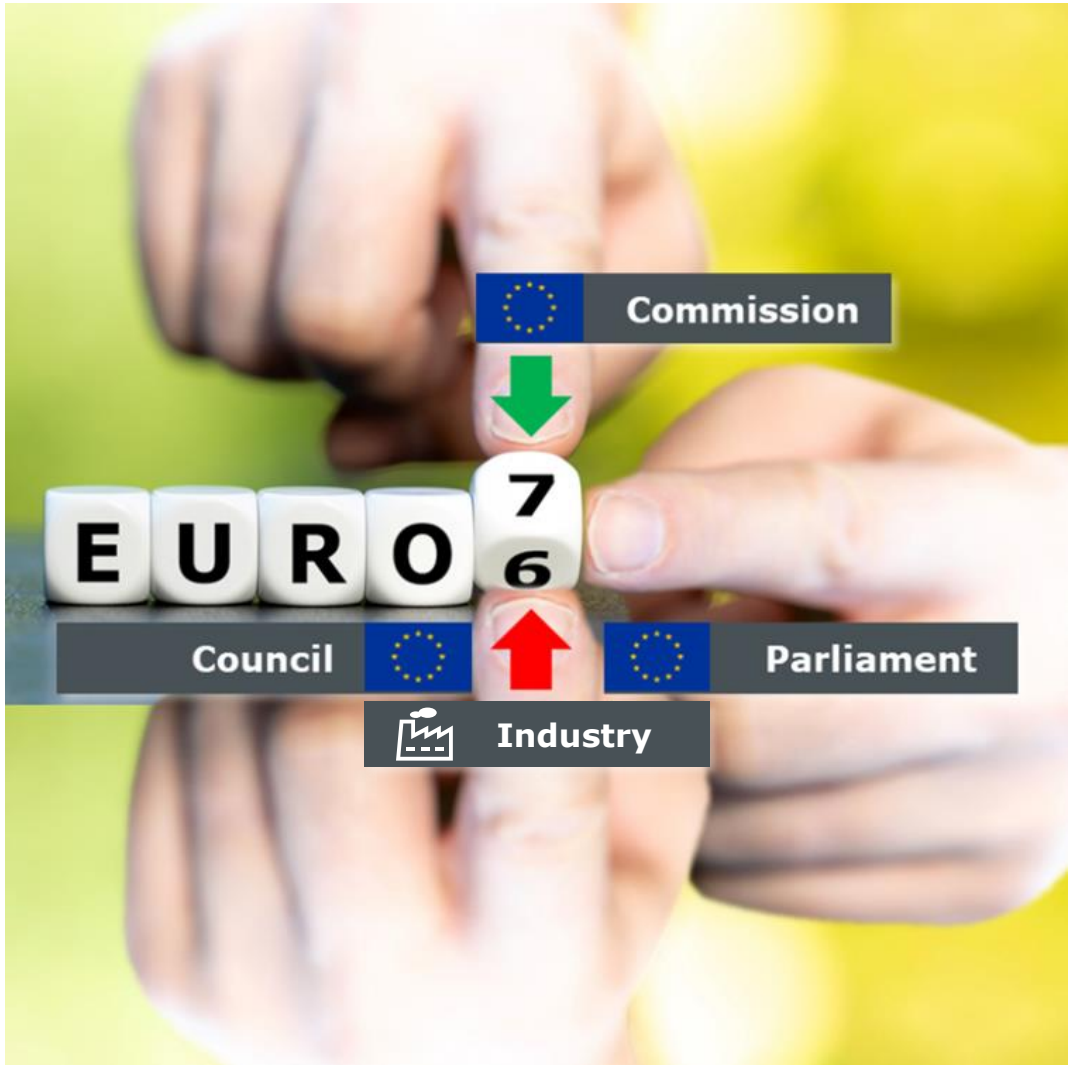
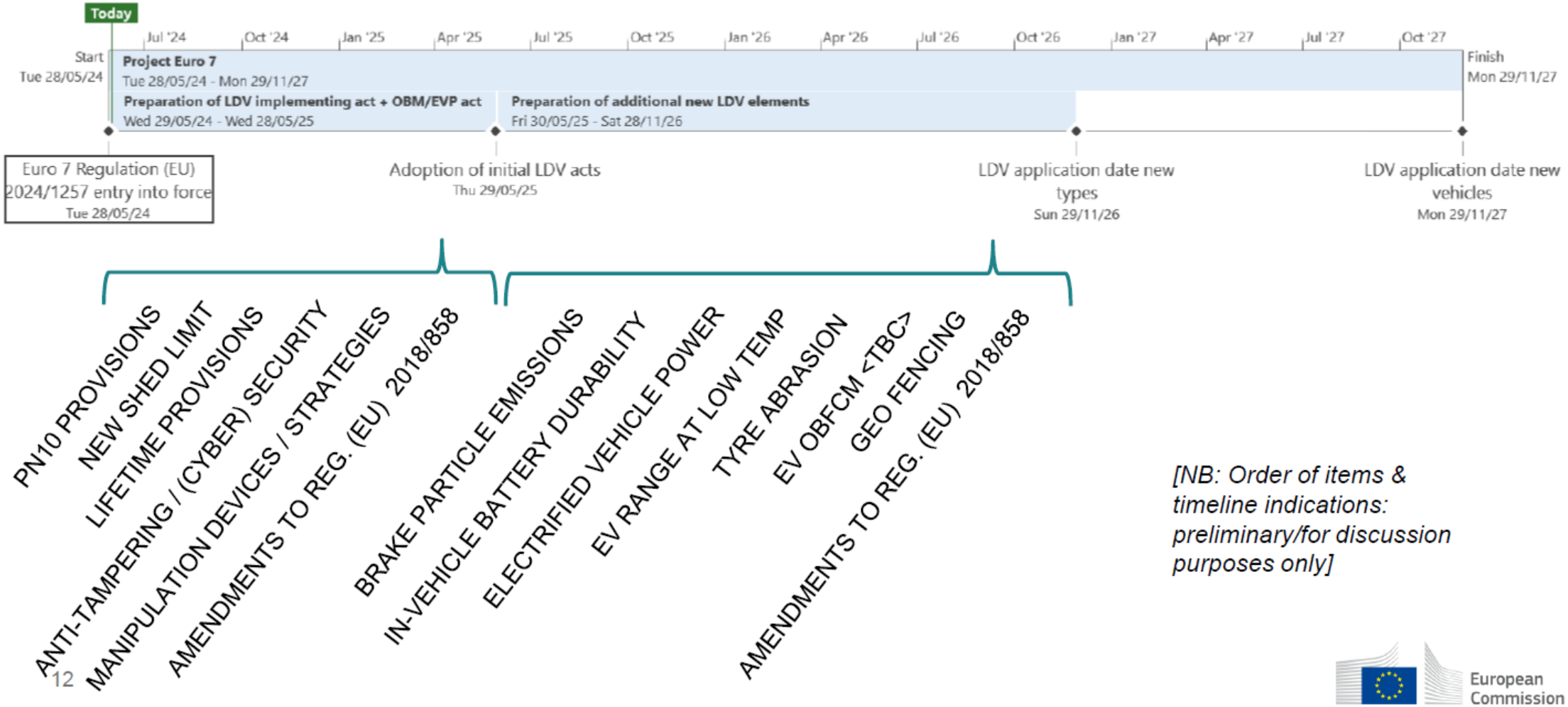
# Euro 7 Legislation:




- After 5 years of consultations, meetings and documents, Europe has reached a general decision about Euro 7. Considering the amount of work done, the outcome is low.
  - It doesn't meet the European Green Deal.
  - It might fail the up-coming air quality standards.
- For pollutant tailpipe emissions there are:
  - Challenges for heavy duty vehicles
  - Only minor improvements for light-duty vehicles.
- Improvements are for e-mobility, brake wear, tier micro plastic and On-Board Monitoring.
- **Implementing (technical) details are still open und shall be defined until mid 2025.**

# Euro-7 – Timeline (Preliminary for LDV Implementing act)

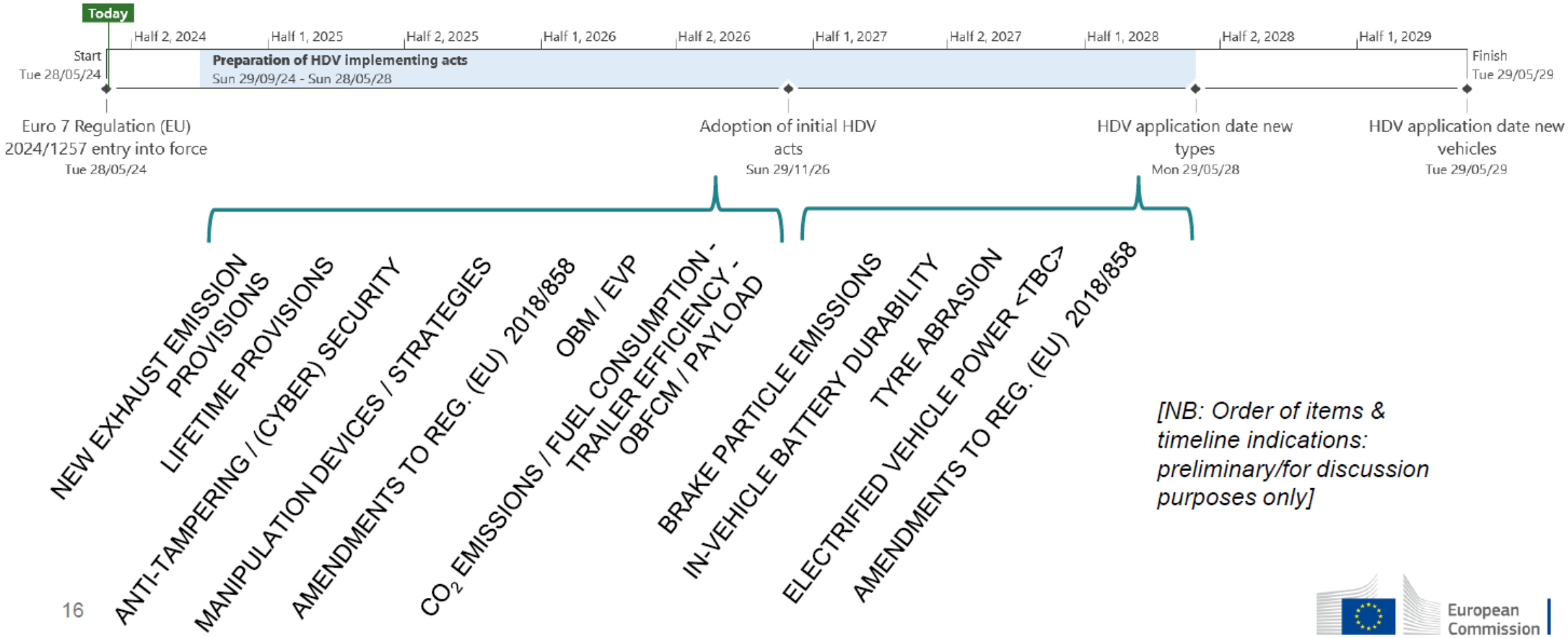



*[NB: Order of items & timeline indications: preliminary/for discussion purposes only]*



European Commission

# Euro-7 – Timeline (Preliminary for HDV Implementing act)

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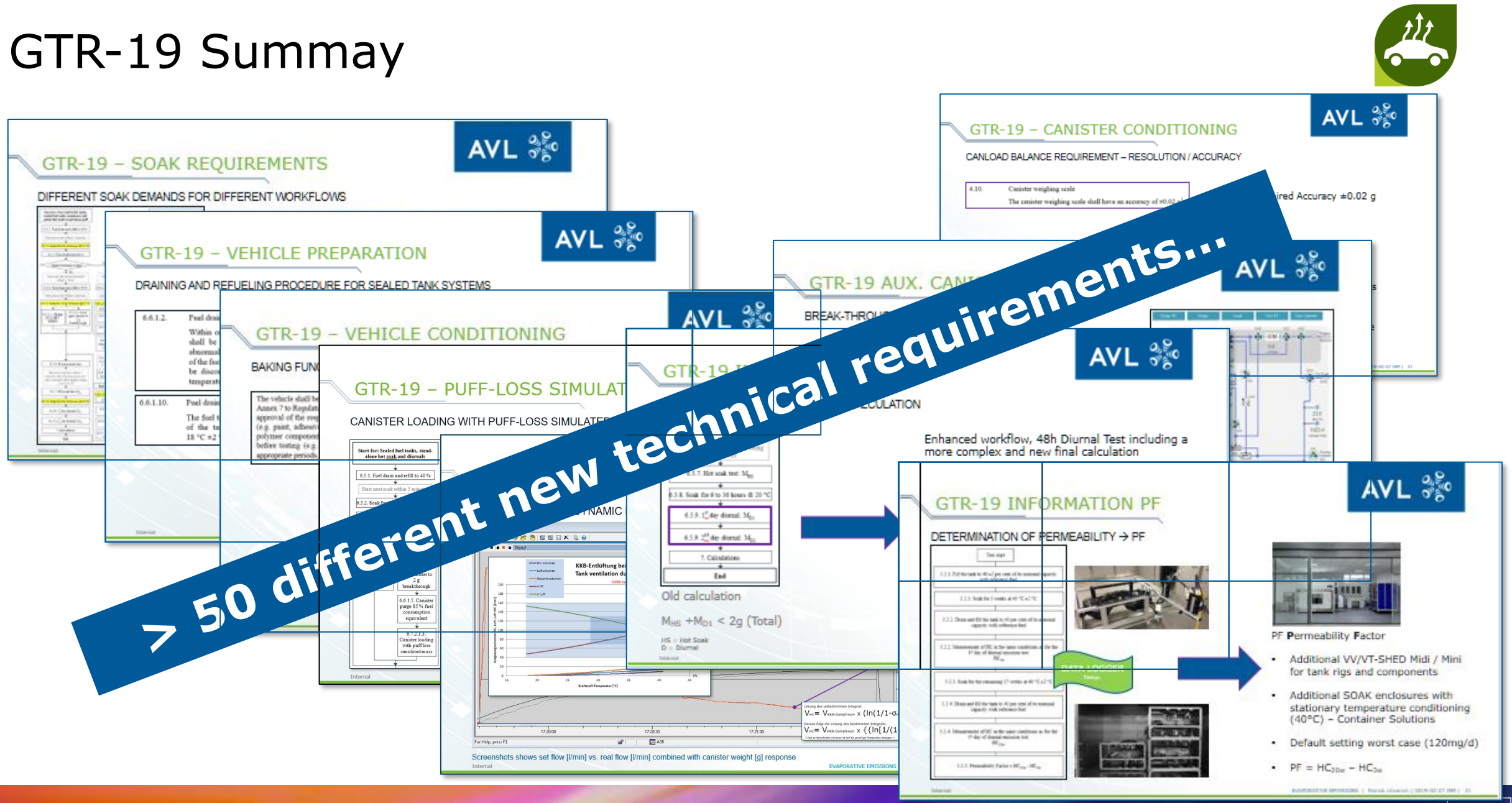
16

European Commission

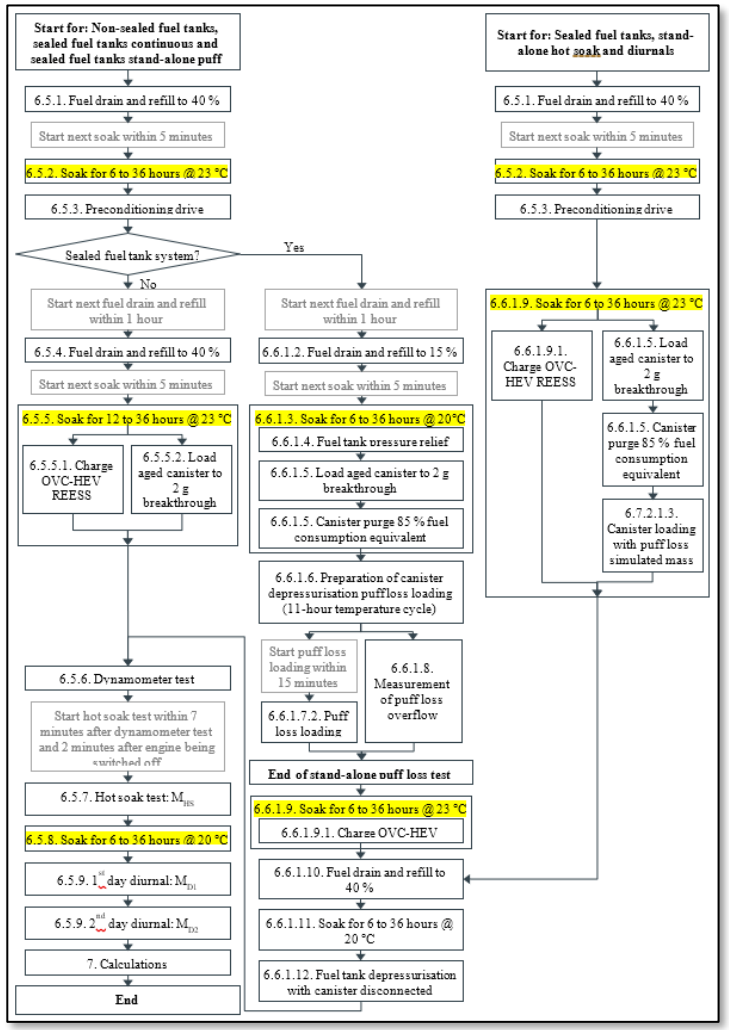
# EU6e/EU7 Evaporative Emission Requirement

# GTR-19 Summay



# GTR-19 – Soak Requirements

## DIFFERENT SOAK DEMANDS FOR DIFFERENT WORKFLOWS




SOAK 20 → 20°C ± 2°C
SOAK 23 → 23°C ± 3°C


**"Tail pipe SOAK"**
SOAK -7°C
SOAK 14°C
SOAK 23°C

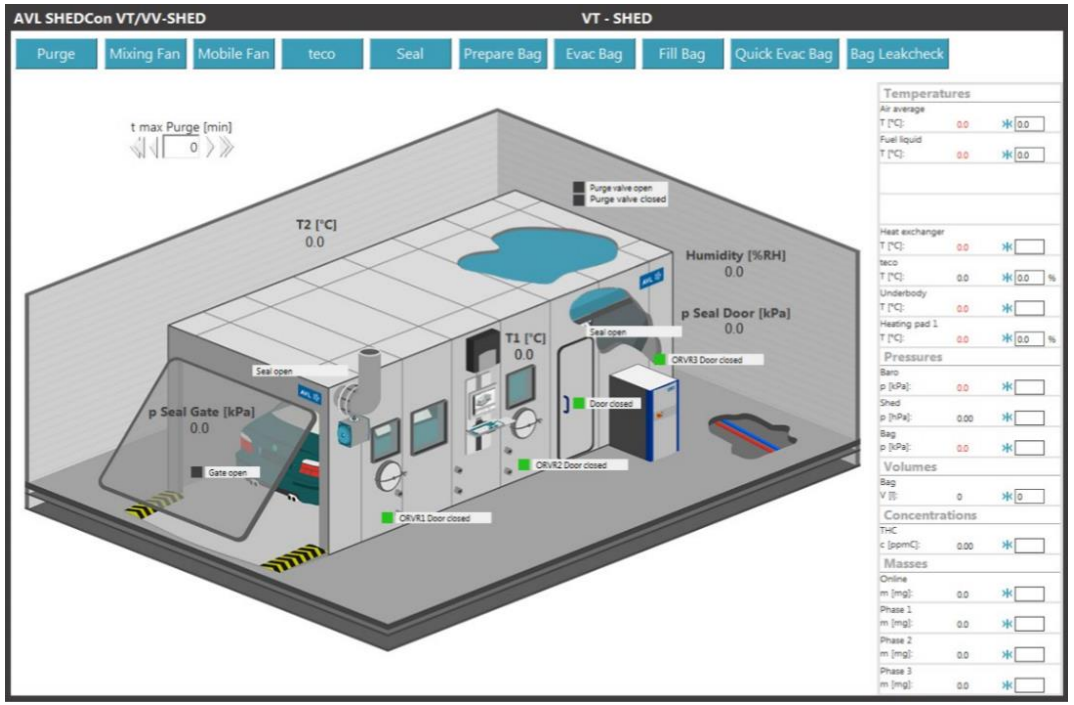
May requires additional SOAK areas, SHED functionality or conditioning container solution

New SHED temperature settings for SOAK procedures and combined SOAK/Diurnal test templates required

# GTR-19 – Vehicle Conditioning

## BAKING FUNCTION FOR VEHICLES OR VEHICLE COMPONENTS

The vehicle shall be prepared in accordance to paragraphs 5.1.1. and 5.1.2. of Annex 7 to Regulation No. 83-07. At the request of the manufacturer and with approval of the responsible authority, non-fuel background emission sources (e.g. paint, adhesives, plastics, fuel/vapour lines, tyres, and other rubber or polymer components) may be reduced to typical vehicle background levels before testing (e.g. baking of tyres at temperatures of 50 °C or higher for appropriate periods, baking of the vehicle, draining washer fluid).

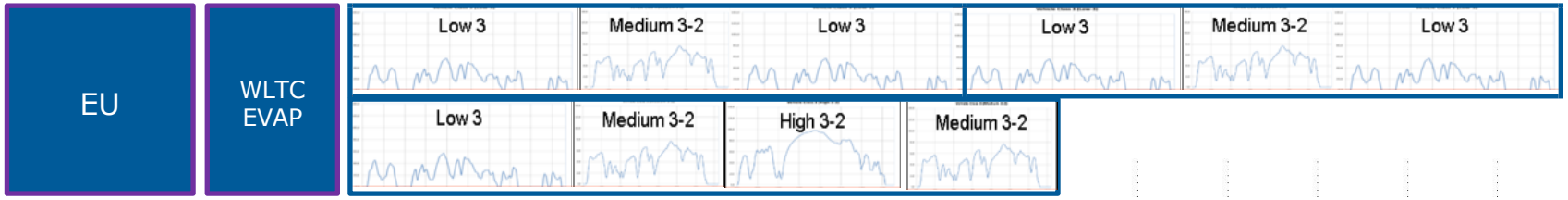



High temperature request of e.g. 50°C or higher…
Additional baking containers or enclosures required

# GTR-19 Vehicle Pre-conditioning

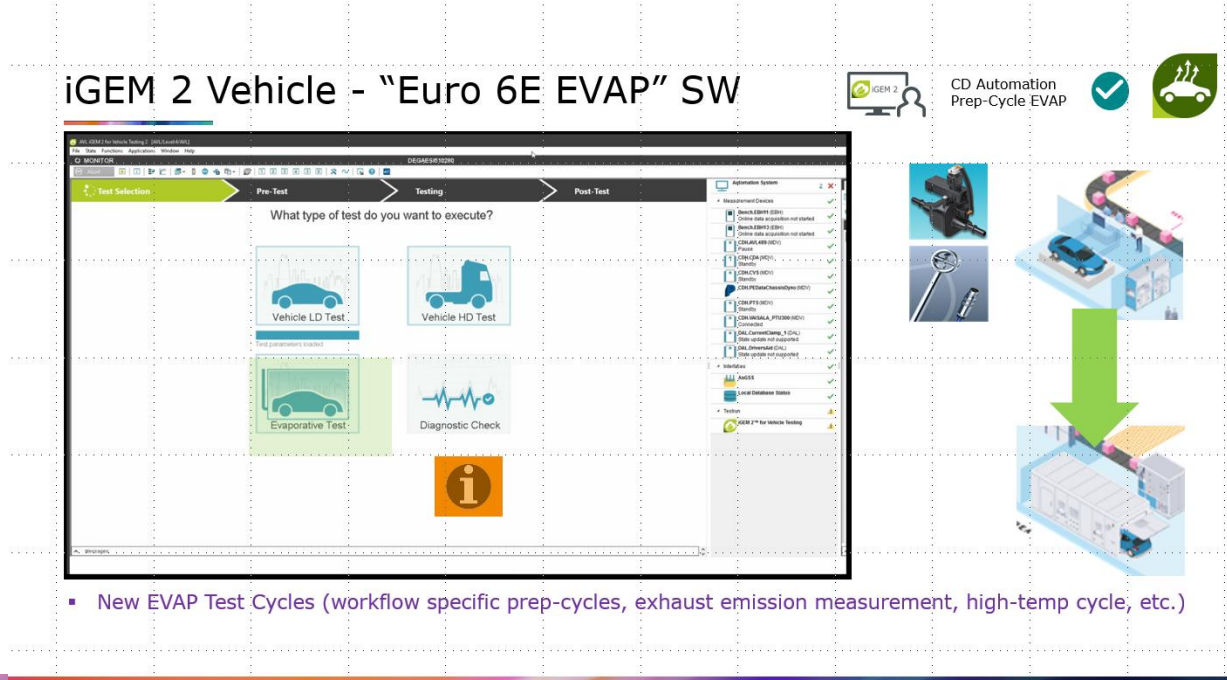
## CANISTER CONDITIONING - PURGE

New additional EVAP-specific pre-conditioning cycles. The phases are coming from the WLTC phases, but the sequence is different compared to the WLTC test runs for tailpipe emissions.



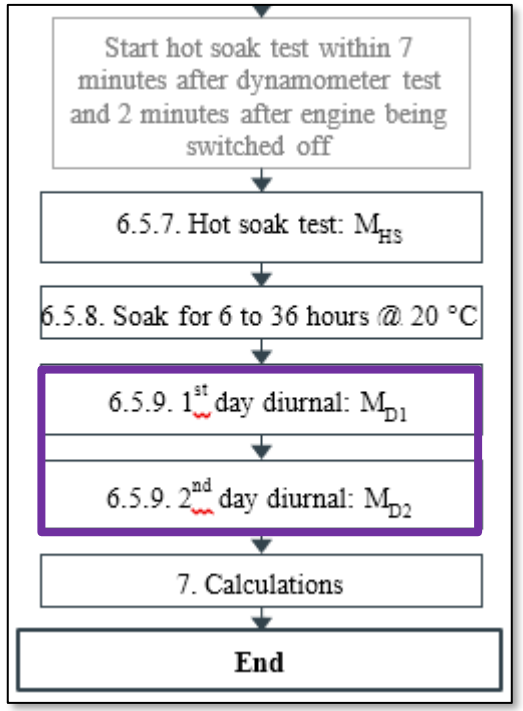

New EVAP pre-conditioning cycles in Chassis dyno automation system.

For OVC-HEV, emission measurement might be required for emission and fuel consumption type approval.



# GTR-19 Testing Calculation

## DIURNAL SHED VEHICLE TESTING & CALCULATION

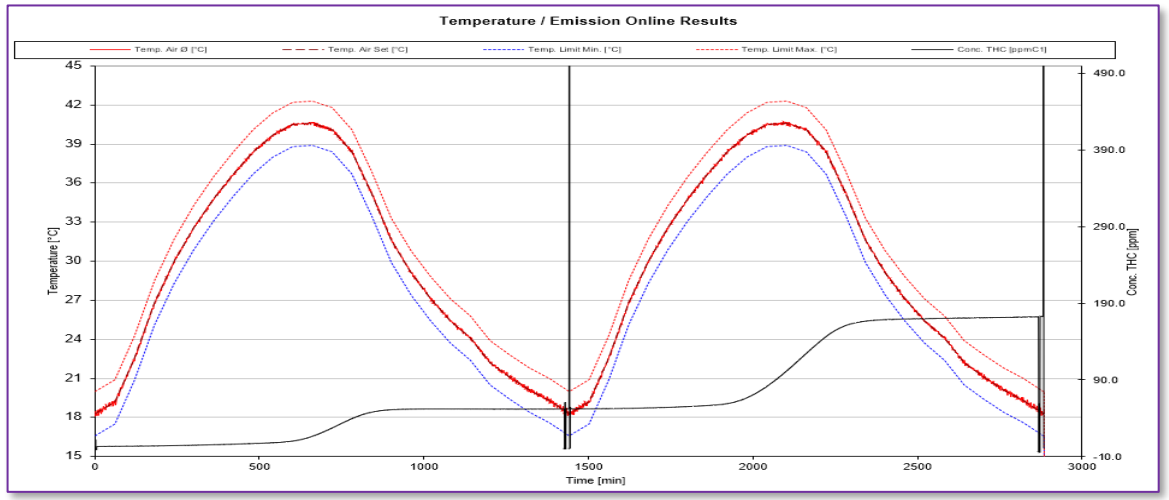



Old calculation

$M_{HS} + M_{D1} < 2.0$ g (Total)

HS = Hot Soak
D = Diurnal

Enhanced workflow, 2 days Diurnal Test including a more complex and new final calculation



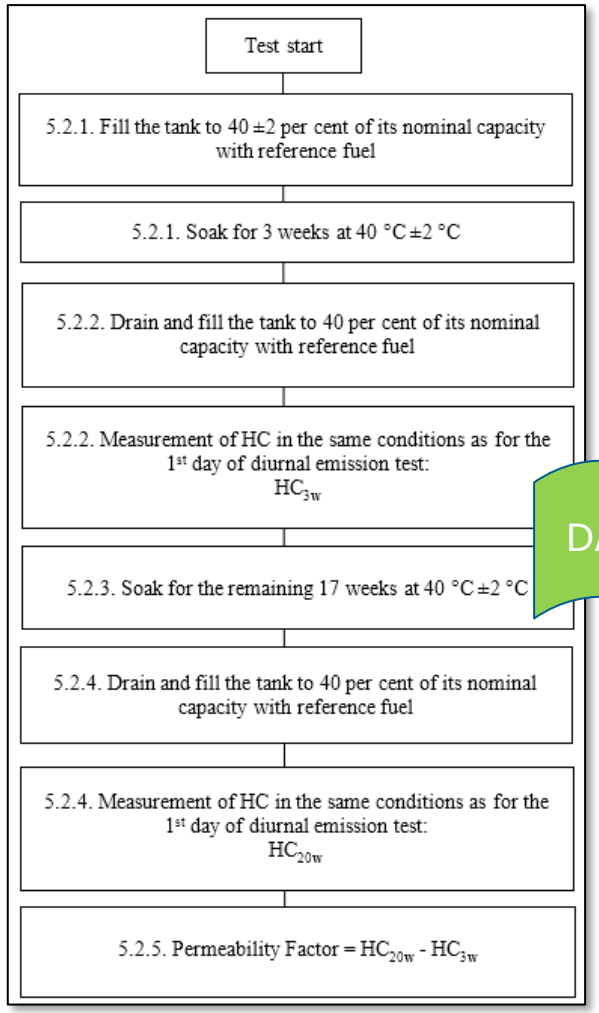

New calculation

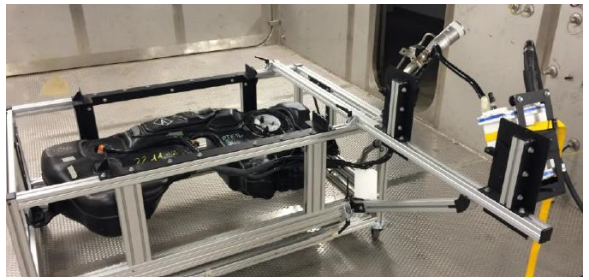
$M_{HS} + M_{D1} + M_{D2} + PF + PF < 2.0$ g (EU 7: 1.5 g)

(Instead of reducing the Limit they modify the calculation → same effect)

# GTR-19 **P**ermeability **F**actor (PF)

## DETERMINATION OF PERMEABILITY → PF



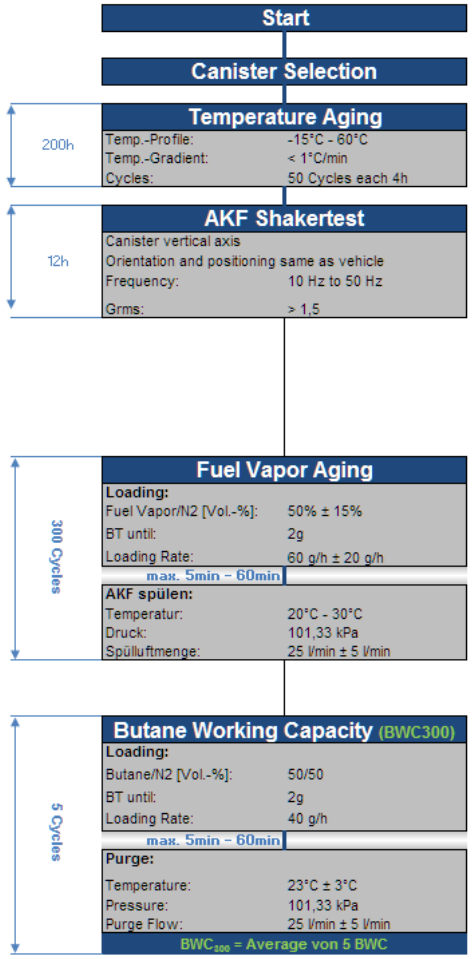
DATA LOGGER
Temp.

PF **P**ermeability **F**actor

- Additional VV/VT-SHED Mini / Micro for tank rigs and components
- Additional SOAK enclosures with stationary temperature conditioning (40°C) – Container Solutions
- PF = $HC_{20w}$ – $HC_{3w}$
- Assigned Permeability Factor (APF) (120 mg/day)

# GTR-19 Canister Aging

## FUEL VAPOR CANISTER AGING AND STABILISATION

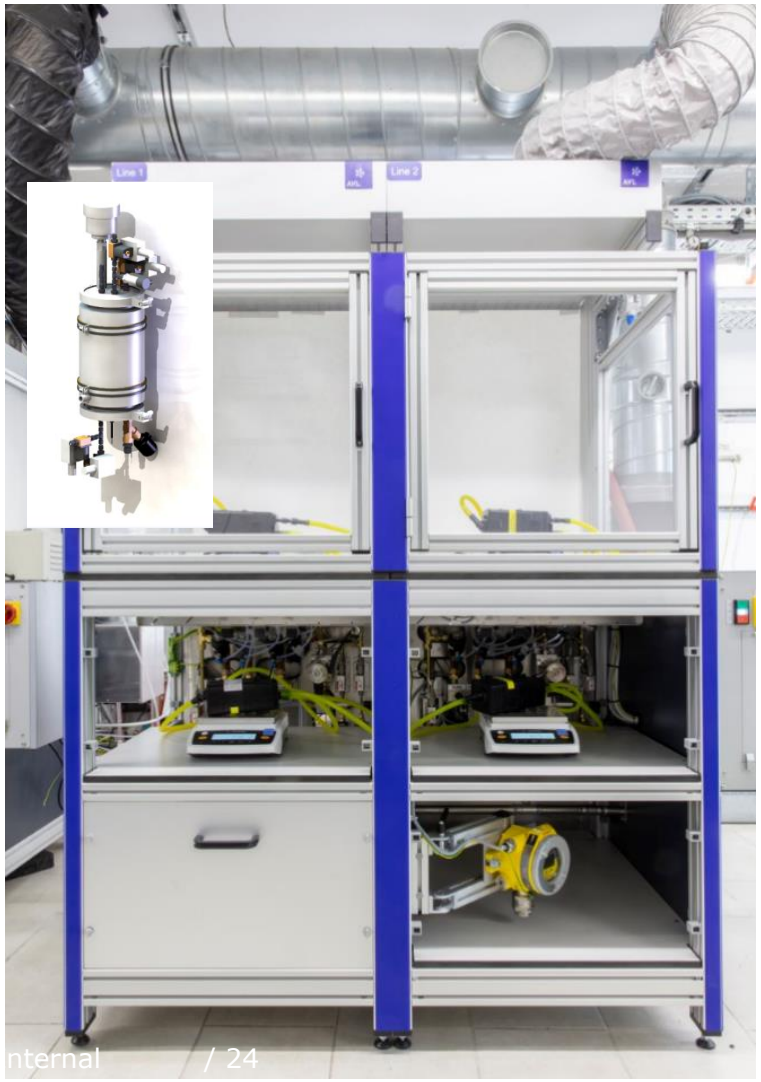



Combined test system setup
Butane + Fuel

Fuel vapor/$N_2$ stabilization (300 cycles) followed by 5 cycles Butane/$N_2$

→ BWC validation

# GTR-19 Typical Lab Setup – Canload 2L-BF



Typical lab setup for standard vehicle conditioning as well as for long-term canister aging and stabilization.

It fulfils all global regulation and provides R&D options like

- ✓ Dynamic canister purge
- ✓ Dynamic canister loading profiles
- ✓ Heated housing with online gas mixture validation
- ✓ High accurate balances 0.01g
- ✓ High purge rate capability for PHEV (boost pump simulation) up to 100 l/min
- ✓ Integrated safety functions (%LEL sensor, active exhaust flow module with flow detection – dp, facility interface)
- ✓ Etc.

# AVL SlimLine™ Systems

# AVL: Ready Today For Tomorrow

# Emission CD

EU-5/6b | Hybrid+BEV+FC | EU-6d | EU-7 | R&D

## Devices/Systems:

- Engine On/Off detection
- Battery simulator for R&D

## Devices

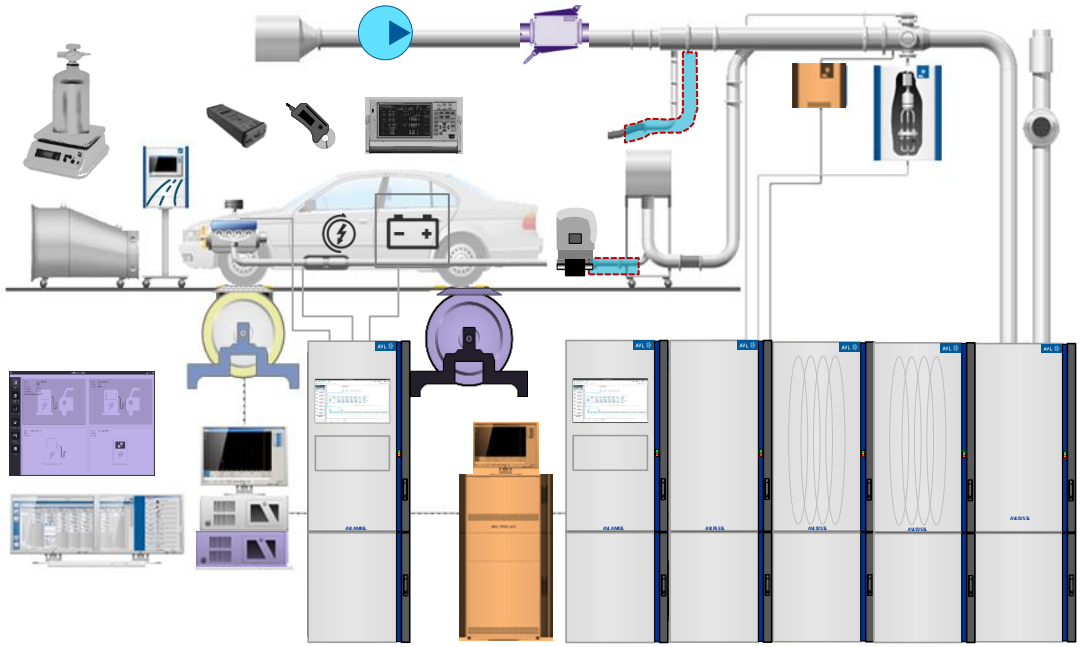
- Cooling fan
- 1 axle chassis dyno
- 2nd chassis dyno axle
- RDE drivers aid

## Automation system:

- Drivers aid
- Test control computer
- Result reporting
- Hybrid UNR-101, CFR1066
- Repeating tests and parallelization of functions
- WLTP (GTR-15)
- Soak area charging software integration
- PEMS integration
- Road-2-Lab

## Emission Chassis Dyno Laboratory

- High Voltage safety precautions and battery fire safety



## Soak area

- Temperature (-7, 14, 23°C)
- Battery charging stations
- Power analyzers

## Test cell conditioning

- Temperature (-7, 14, 23°C)
- Humidity conditioning
- Altitude €€€

## CVS:

- Constant volume sampler
- PM sampler
- PN sampler 10nm (23nm)
- CVS for repeating tests
- CVS bags for 4 phases
- Heated exhaust transfer lines
- Tailpipe pressure control
- Flow Sonix dilution air flow

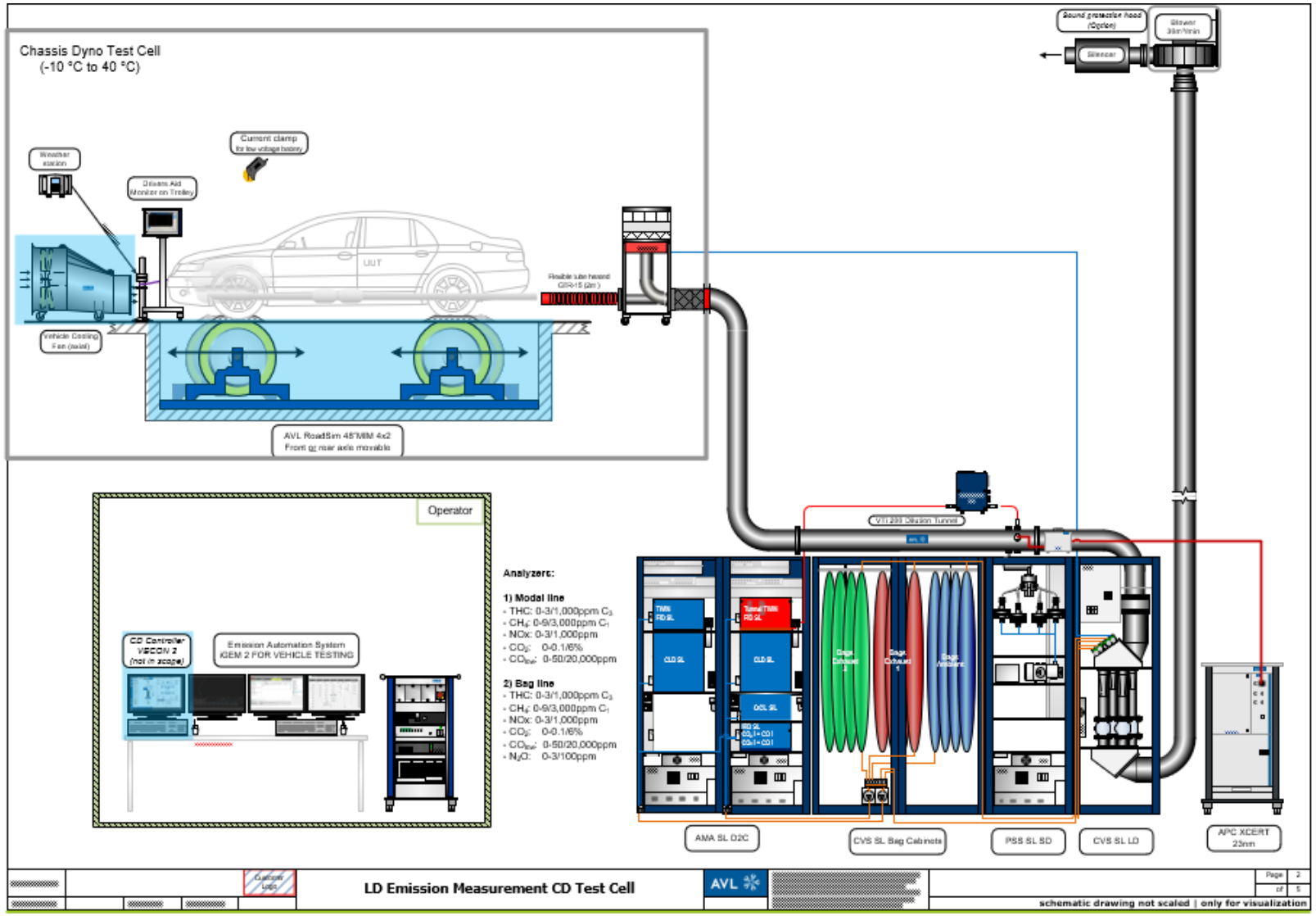
## Emission analyzers:

- Diluted emission bench
- PEMS (+ validation on CD)
- ~~Additional pollutants (FTIR, QCL)~~
- Pre-Post cat emission AMA R2, APC, Micro Soot

## Energy measurement:

- Power analyzer propulsion B
- $H_2$ consumption (scale)
- Current clamp 12V battery

# AVL Solution for EU 7 Type I/VI test




## Basic Solution

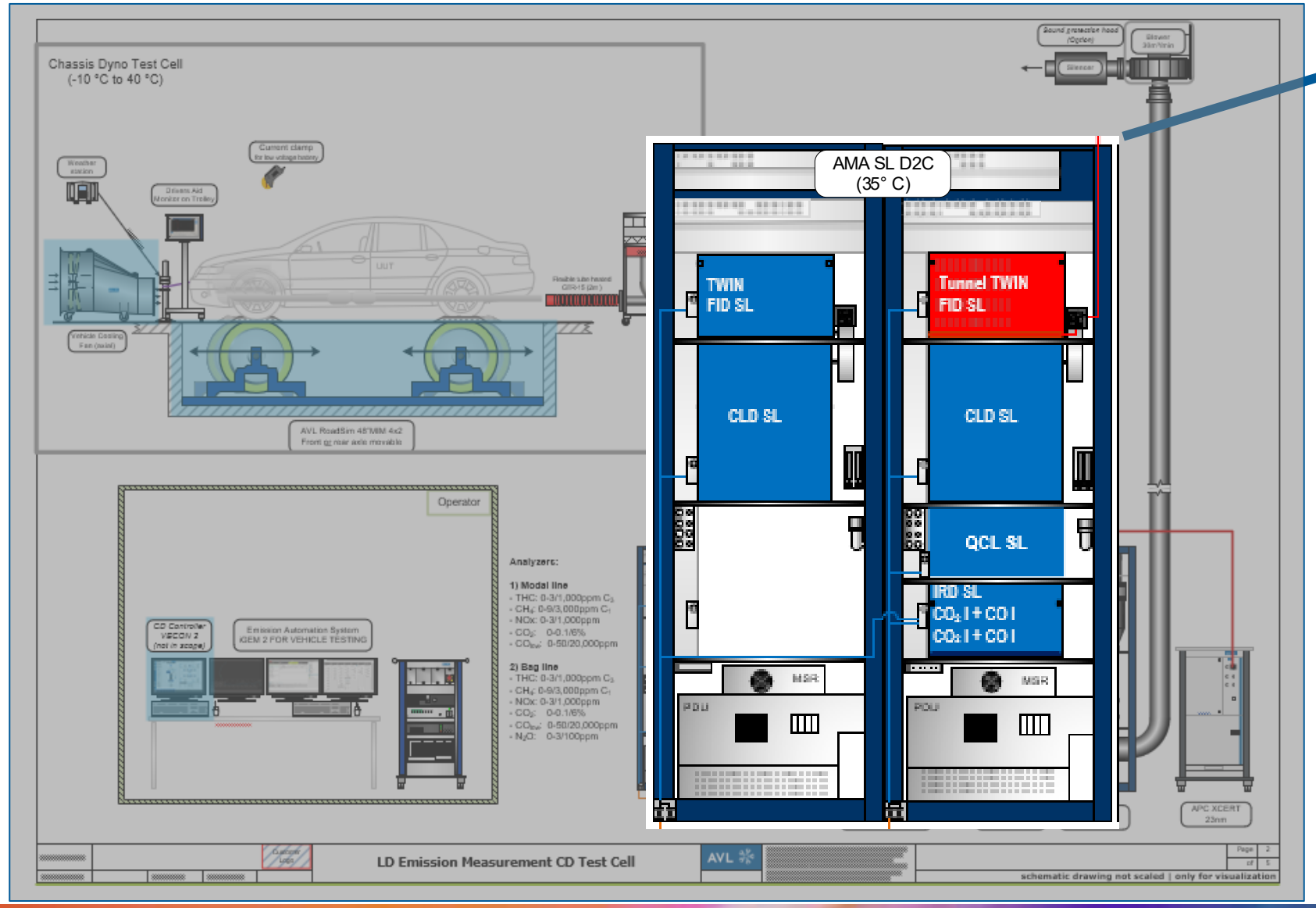
- Cost efficient solution
- Mainly for certification and certification type of development
- Fulfilling all legislation requirements

## The most important Topics

- Gasoline/Diesel
- 4 sample phases for WLTC
- Low Emission capable, Heated CVS
- Particulate mass and particle number measurement for all vehicles
- 12V battery State of Charge SOC measurement

...

# AVL Solution for EU 7 Type I/VI test




## 2 lines dilution bench

- Modal dilute measurement in parallel with bag measurement
- Test time saving

Bag measurement:

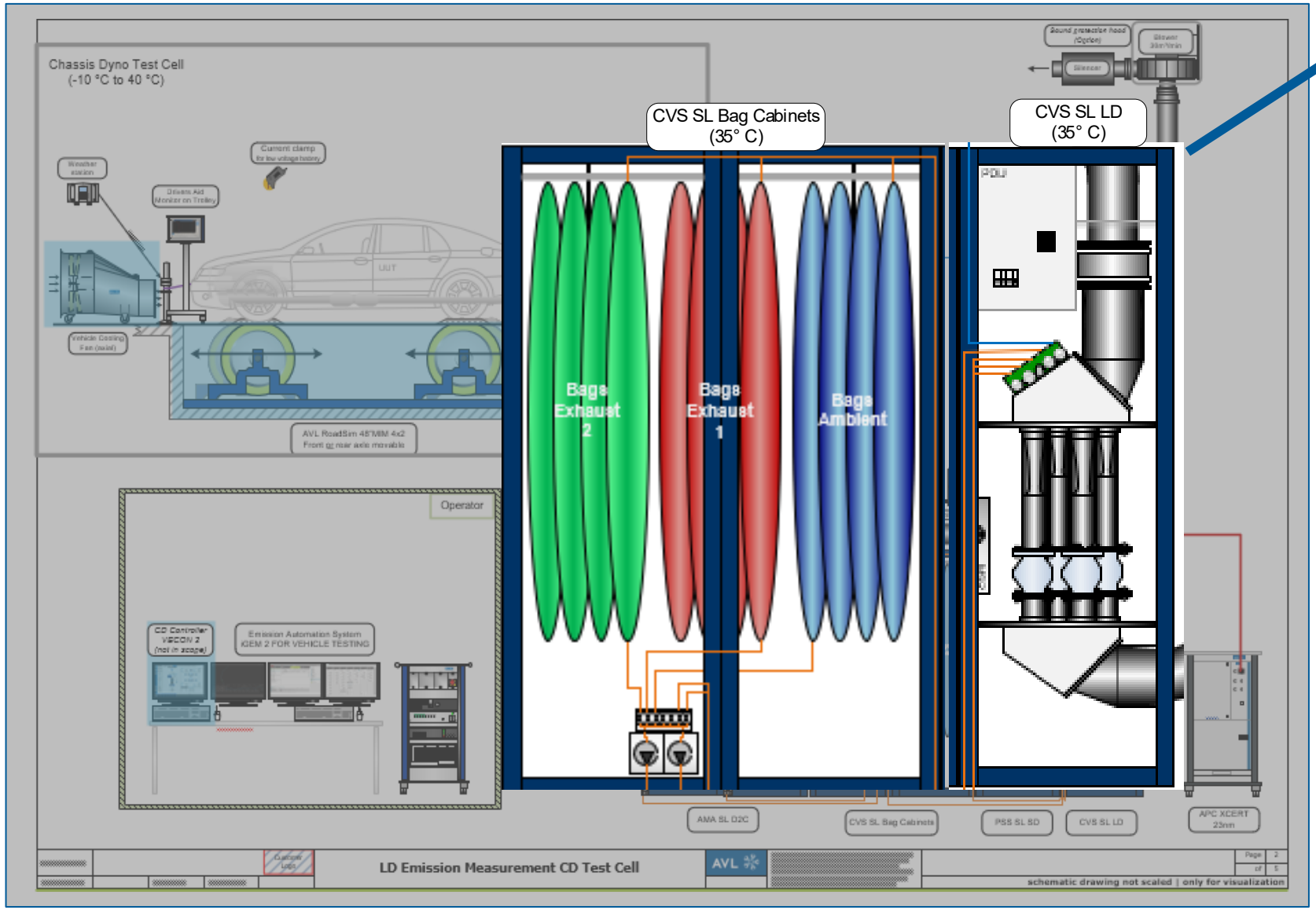
- Tunnel TWIN FID
- CLD LC
- $CO_2$ L
- CO L
- $N_2O$ L

Modal dilute measurement:

- TWIN FID
- CLD LC
- $CO_2$ L
- CO L

- **QCL Stream Switching** for Bag or Modal

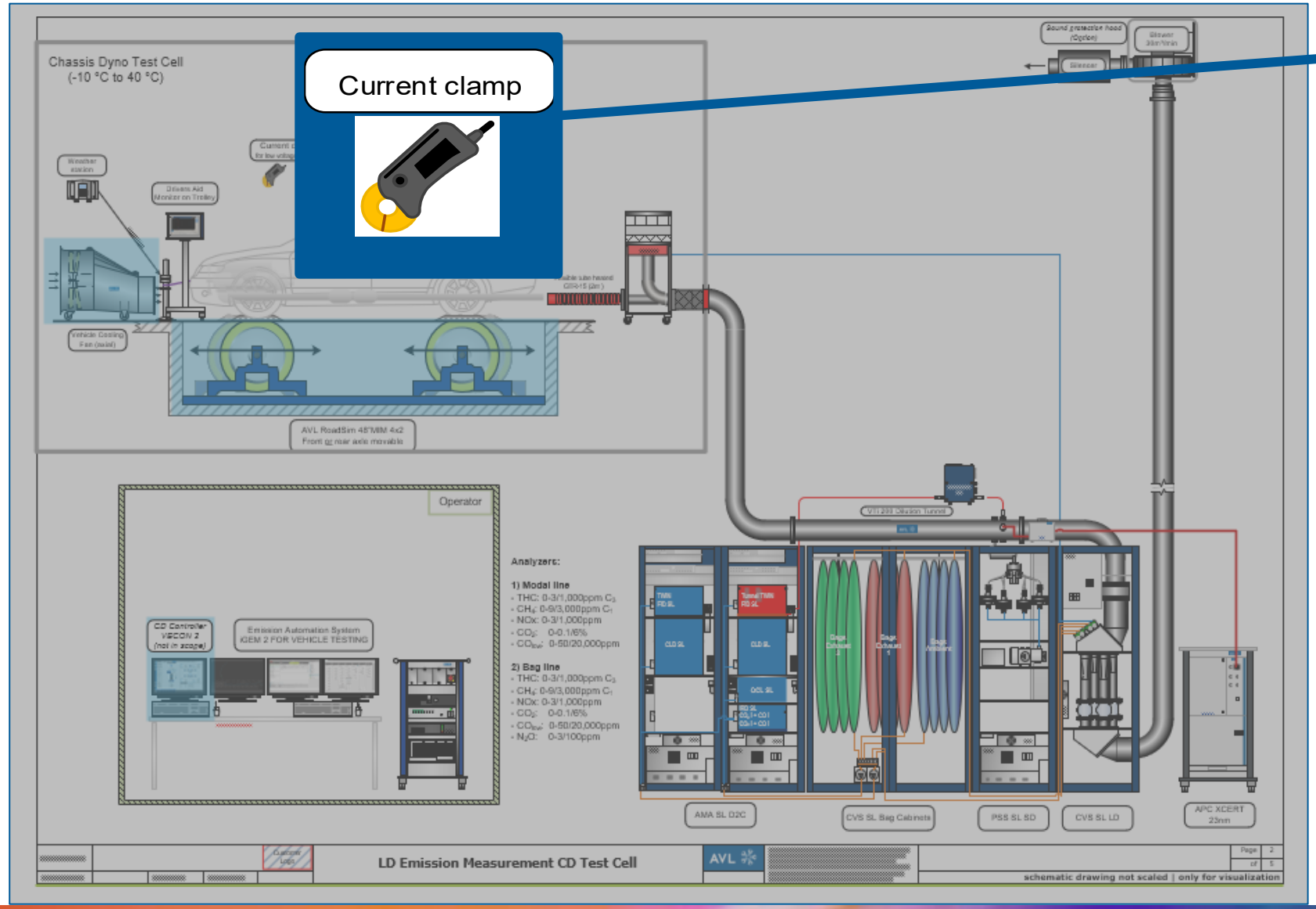
# AVL Solution for EU 7 Type I/VI test




## Heated CVS system

- 4 bag pairs for 4 phase WLTC test
- For low emission measurement
- No need to purify dilution air

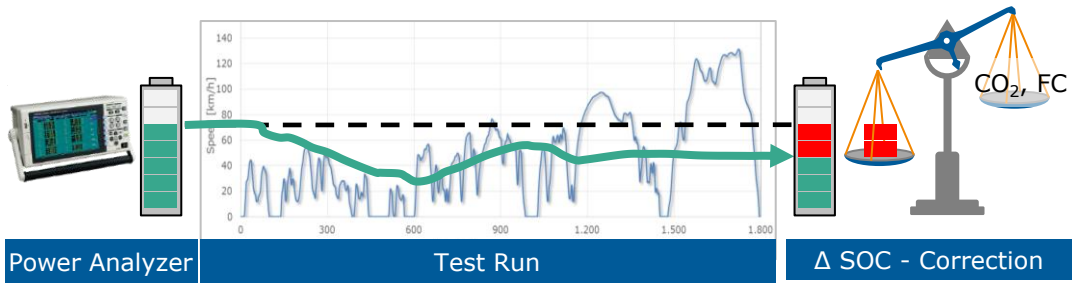
# AVL Solution for EU 7 Type I/VI test




## REESS current measurement

- Low voltage battery current measurement
- For $CO_2$ emission mass correction

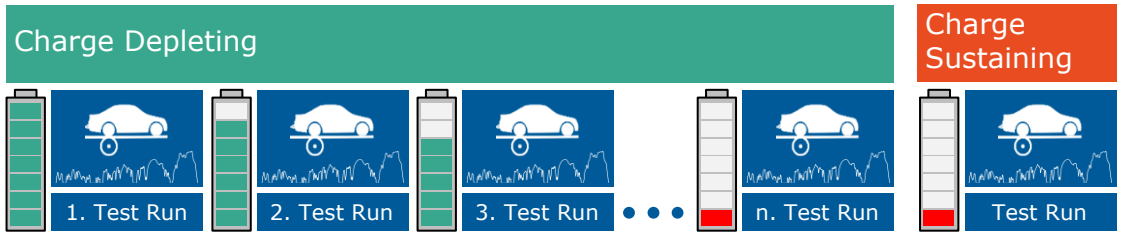
# Hybrid Vehicle Testing




## Hybrid - NOVC (Not Off Vehicle Charging):

The vehicle can move only by the E-motor and batteries are only charged by the IC-engine or breaking, no external charging

- The SOC (State of Charge) is measured before, during and after the test
- If the SOC before and after the test is:
  - the same, $CO_2$ and fuel consumption is as measured
  - different then a ΔSCO correction is applied

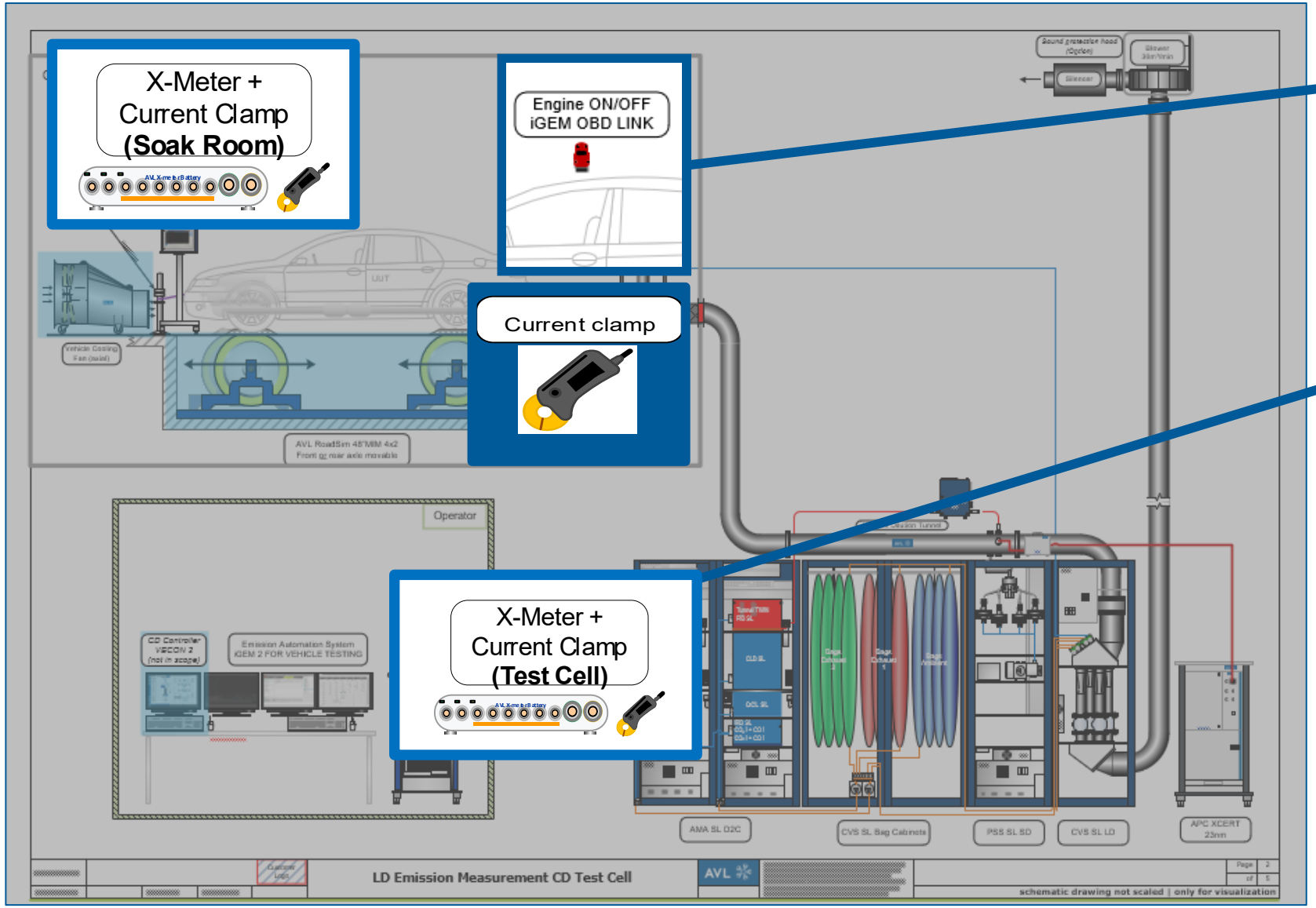



## Hybrid - OVC (Off Vehicle Charging):

The vehicle can move only by the E-motor and batteries can be charged externally (Plug-In Hybrids)

- Testing is complex and time consuming:
  - Charge Depleting mode:
    - Test is started with a fully charged battery
    - One after the other test is executed until the battery is empty or the vehicle starts to charge the battery with the IC engine (reaching Charge Sustaining mode)
  - Charge Sustaining mode:
    - One WLTC test is executed
- A final $CO_2$ and Fuel Consumption result is calculated based on the measured $CO_2$ and fuel consumption values and the number of cycle driven and a charge utility factor.
- Pollutant emissions must be within the limits in all tests.

# AVL Solution for EU 7 hybrid vehicle test



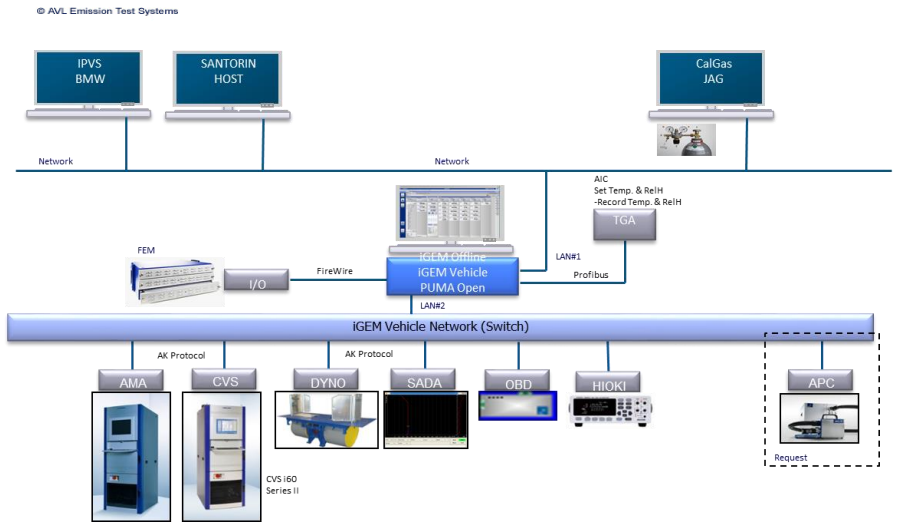

## Basic Requirement

- Engine On/Off detection
- Current Clamp for Hybrid battery
- Power analyzer in **Soak room**
- iGEM 2 Vehicle hybrid package

## Advanced Solution

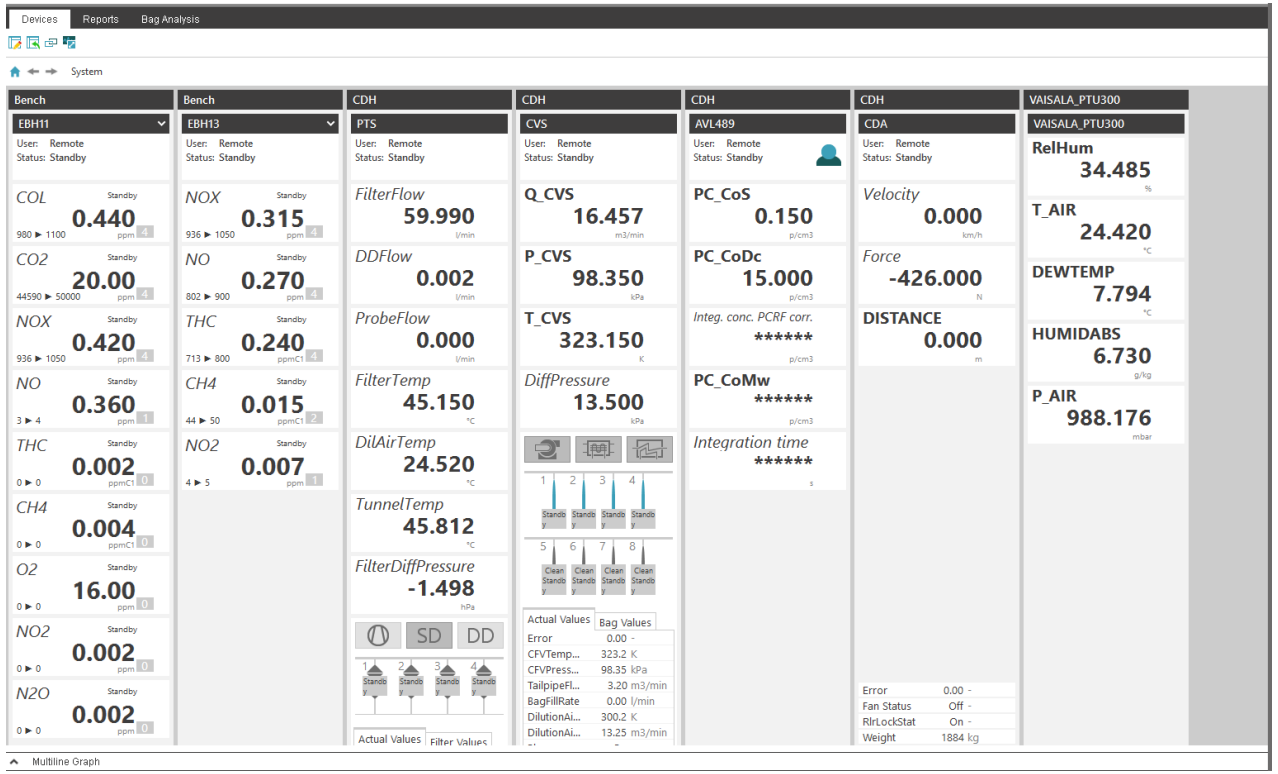
- Power analyzer in **test cell**
- Tailpipe pressure control
- Bag parallel sequences

# AVL Solution for EU 7 hybrid vehicle test




## Automation system

## iGEM 2 Vehicle Online Data Display



# AVL Solution for EU 7 Type I/VI test

## Automation system – iGEM 2 Vehicle

### Calculated from user input

Transmission: Manual

Shift schedule: Dynamic

**Dynamic Gear Shift Determination Inputs**

| | | | |
|---|---|---|---|
| Rated power: | 200 kW | Idle speed: | 700 1/min |
| Number of gears: | 5 - | Rated speed: | 3,300 1/min |
| Engine full load curve: | SpeedToPower | | |

| Gear Engine/Vehicle Speed Ratios | | Gear Minimum Engine Speeds | |
|---|---|---|---|
| ndv1 | 125 - | 1 | 600 1/min |
| ndv2 | 67 - | 2 | 750 1/min |
| ndv3 | 46 - | 3 | 850 1/min |
| ndv4 | 35 - | 4 | 1,000 1/min |
| ndv5 | 29 - | 5 | 1,200 1/min |
| ndv6 | 20 - | 6 | 1,300 1/min |
| ndv7 | 15 - | 7 | 1,400 1/min |

### Read from CSV File

Transmission: Manual

Shift schedule: External

External Shift schedule: GS input 150306

**CSV File local, or on shared file server**

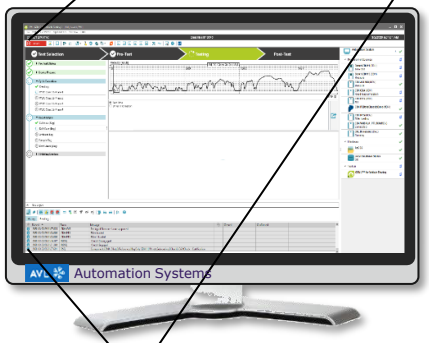
| **\Data File Information:** | | |
|---|---|---|
| File ID | | 417A_V60_10020m1500_123 |
| Version | | 1 |
| | | |
| ... removed sections .... | | |
| | | |
| **\Gear Shift Data:** | | |
| Second | gear | clutch |
| 0.00 | 0 | 0 |
| 14.00 | 1 | 0 |
| 17.00 | 2 | 1 |
| 20.00 | 3 | 0 |
| 24.00 | 4 | 0 |
| 32.00 | 5 | 1 |
| 39.00 | 4 | 0 |
| 44.00 | 3 | 0 |
| 49.00 | 2 | 1 |

Table 2 – CSV File Format

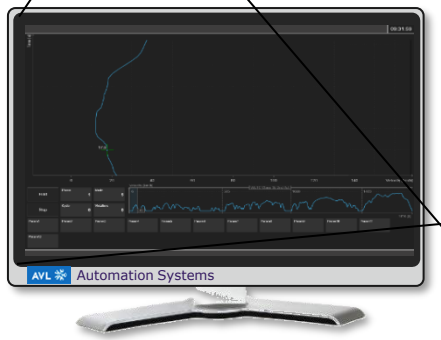
# AVL Solution for EU 7 hybrid vehicle test

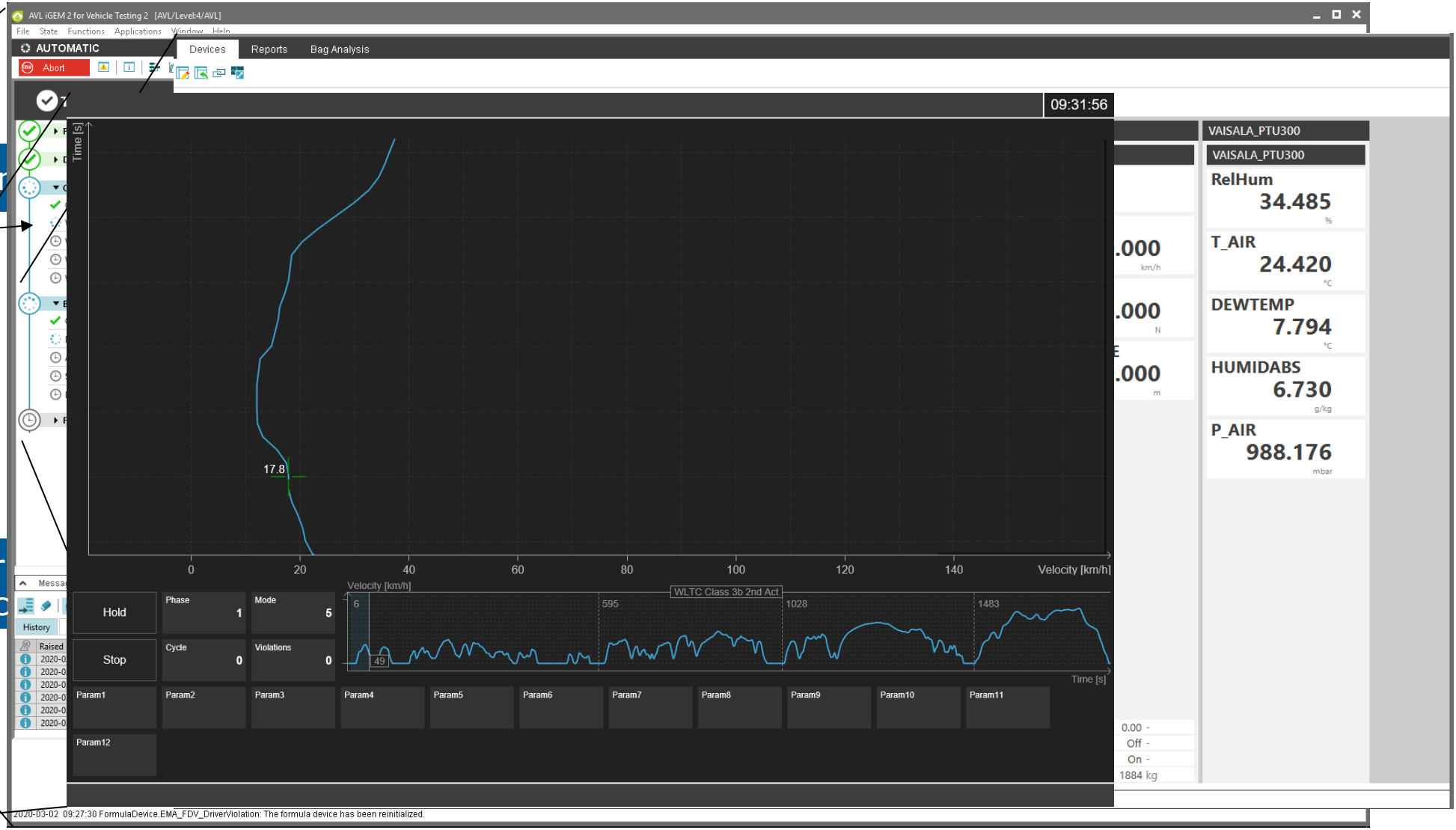
iGEM 2 Vehicle Autor

Test Started



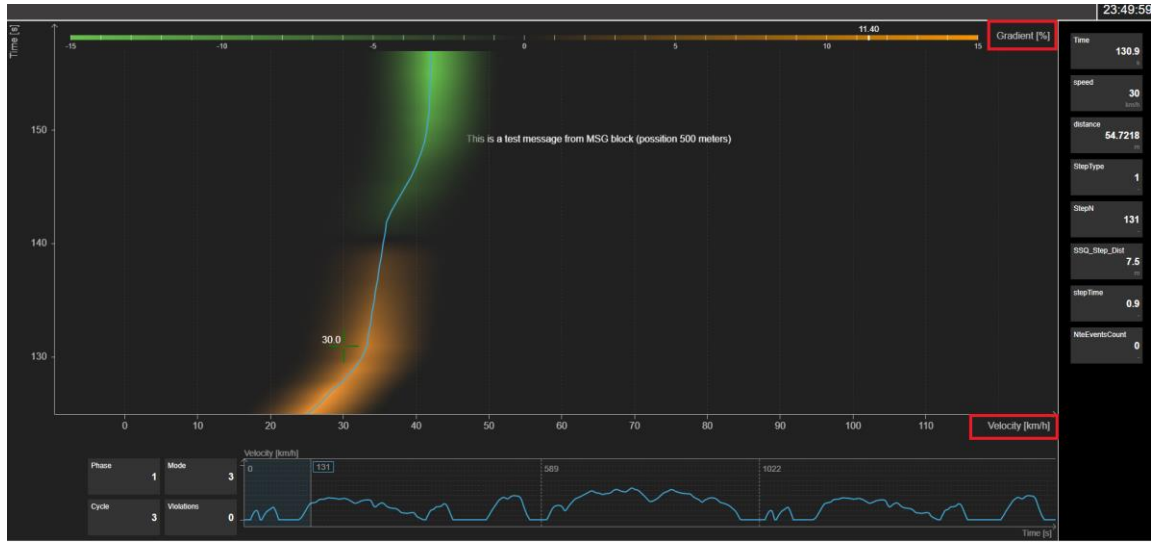

Driver
Driver test c



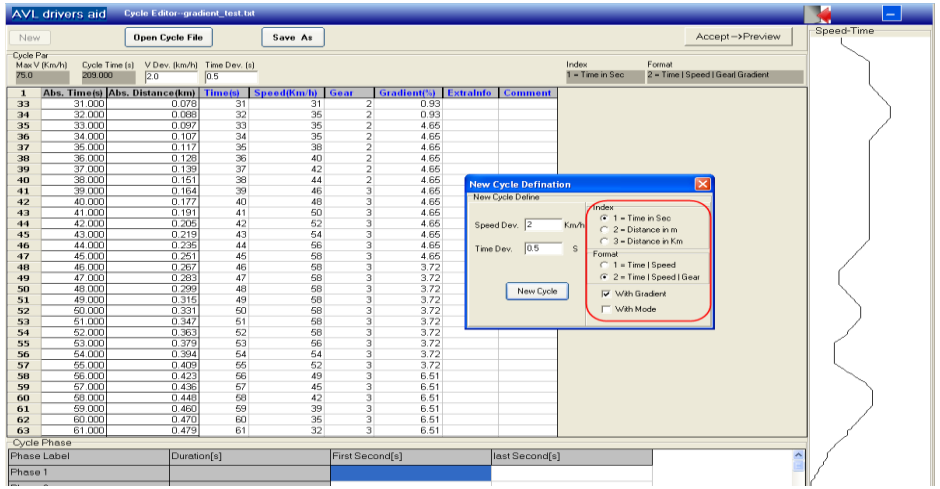




Web based Data Access for measured values

# AVL iGEM 2 Vehicle: ideal for RDE




- Full AVL tool chain integration
- Devices synchronization
- Automatic data management
- Automatic correlation report & status




- **Chassis dyno must support gradient simulation**

# Summary

# AVL SlimLine™

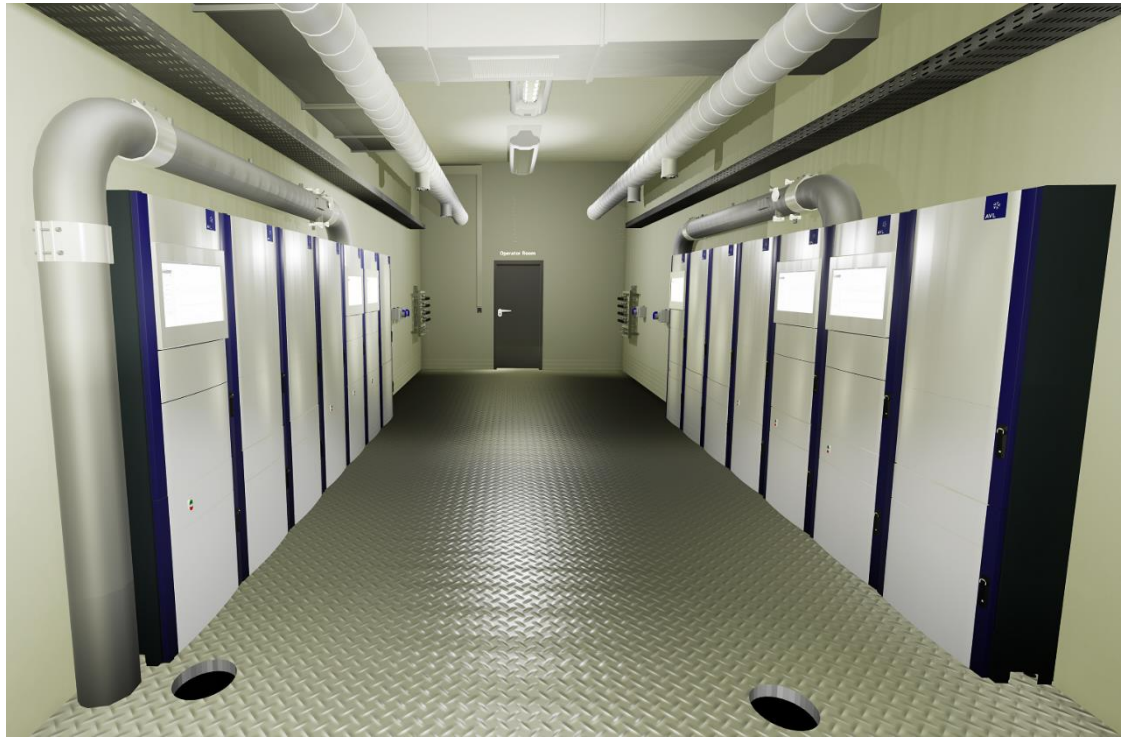

297 mm i.e. a show size EU 41 or US 8

## AVL SlimLine™

- Complete product line
  - Emission Bench AMA
  - Constant Volume Sampler CVS up to 40m³/min as standard
  - Particulate Sampler PSS
- Easy to operate with highest degree of automatic functions accordingly all worldwide legislations
- Fulfills current and foreseeable future worldwide emission legislation
- Smallest Footprint, only 1/3 of all others systems on the market

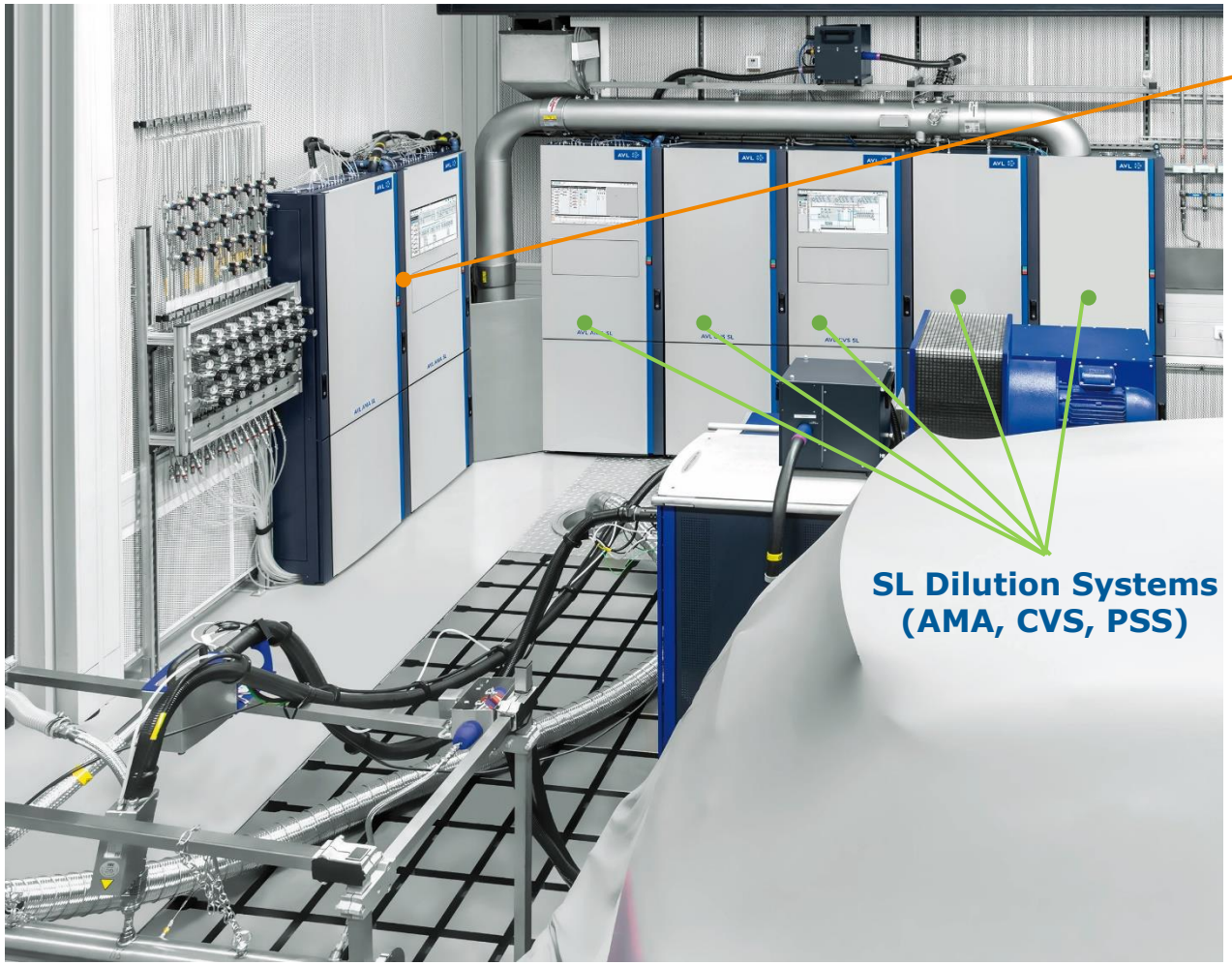
# AVL SlimLine™


Before



After

# AVL SlimLine™ Dilution Systems
## Reference Installation (AVL TechCenter Stuttgart)



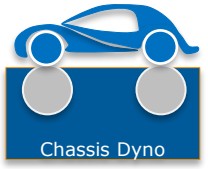

# AVL SlimLine™ Dilution Systems
## Reference: US CARB

### CARB New Facility

Engine Dyno
3 Test Cells
6 Dyno's

**Heavy Duty Engine**

**Small Off Road Engine**



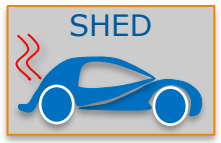

Chassis Dyno
1 Research
1 Climatic
3 Cert LDV
2 HDV
3 Prep (2 LDV 1 HDV)
1 Motorcycle
1 ATV (4wd)

**Light Duty Vehicles**

**Heavy Duty Vehicles**

**Motorcyles**

**Off Road Rec Vehicles**




SHED
1 Running Loss
1 Light Duty
2 Medium Duty

**Light Duty Vehicles**

**Off Road Vehicles**

### AVL Scope:

9 LD CVS

4 HD CVS

30 Emission bench

7 LD Chassis dyno

3 HD Chassis dyno

2 MC Chassis dyno

5 Engine Dyno

4 SESAM FTIR

4 SHED

16 Automation system

Lab Management System


State of California's goal is to have a zero net energy facility

# Worldwide Emission Supplier

# Thank you


www.avl.com