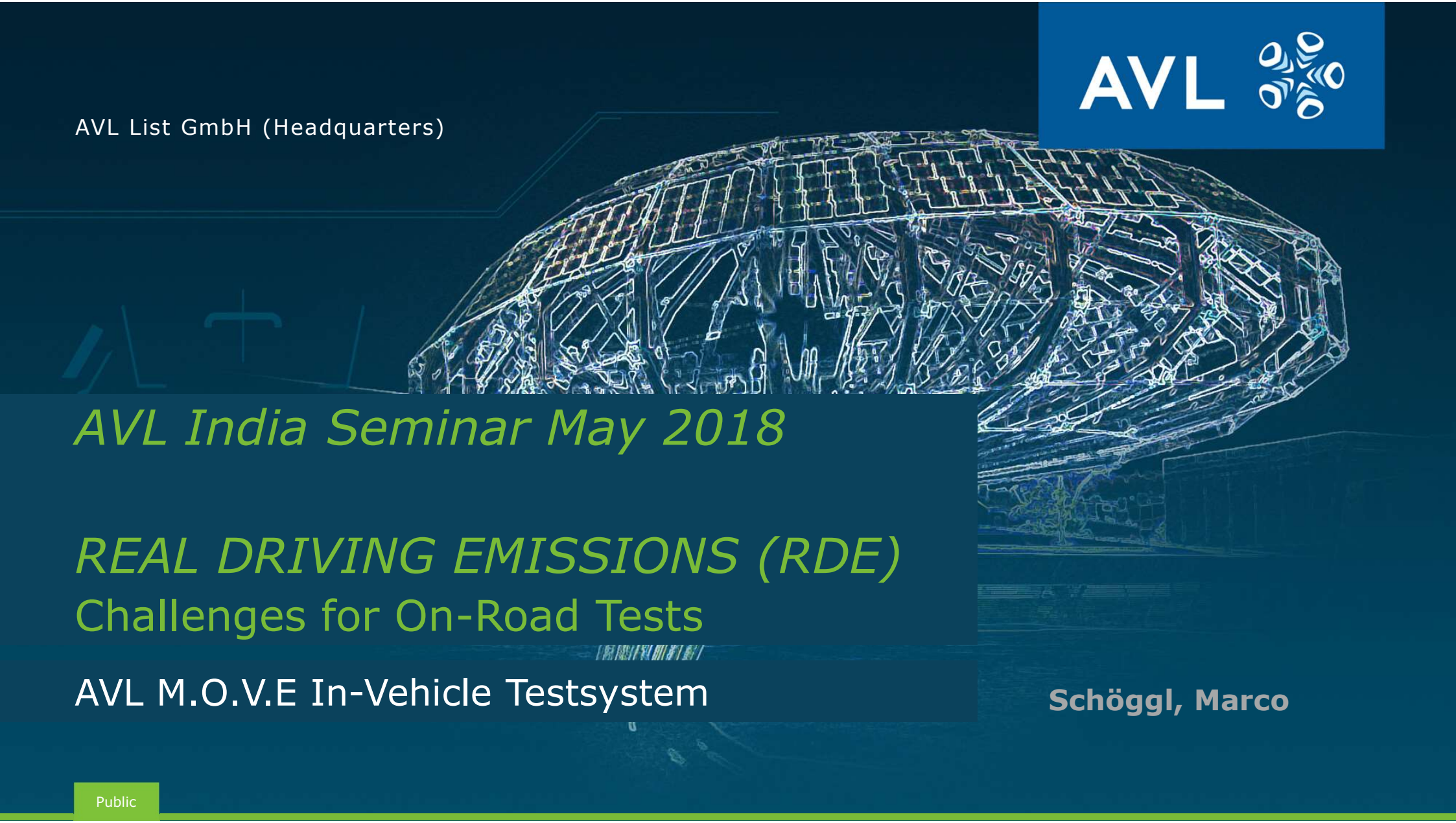
AVL List GmbH (Headquarters)



AVL India Seminar May 2018

REAL DRIVING EMISSIONS (RDE)

Challenges for On-Road Tests

AVL M.O.V.E In-Vehicle Testsystem

Schöggl, Marco

REAL DRIVING EMISSIONS (RDE)
A REAL CHALLENGE FOR ON ROAD TESTING

RANDOMNESS

Driving style has a strong impact on the equipment – shocks and vibrations.

AMBIENT TEMPERATURE

Changing ambient temperatures can strongly impact the quality of RDE test data.

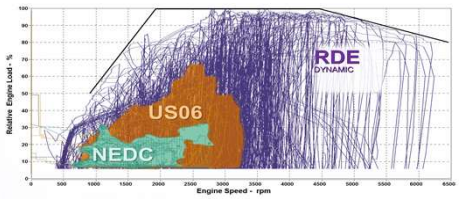
AMBIENT PRESSURE

Changing ambient pressure is the key decision criterion for the selection of PEMS analyzers..

RDE READY

Impact to Emissions

Drive Cycles:



Vehicles must be clean in a much larger area of the engine map:

- NEDC → WLTC
- Real Driving Emissions

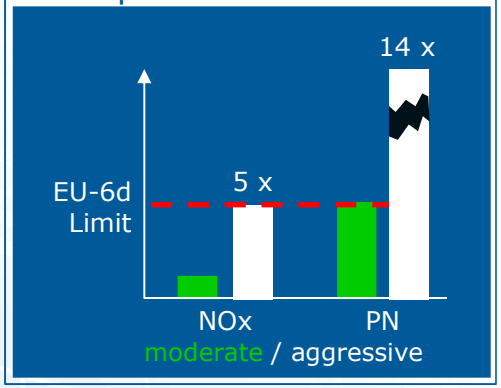
Example:

Drive Style:

Drive style has a large impact (by factors) on emission:

- aggressive
- moderate

Example:

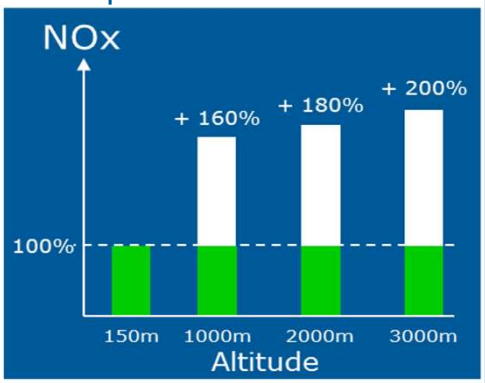


Altitude:

Impact of altitude:

- physical
- calibration, like when EGR is switched off

Example:

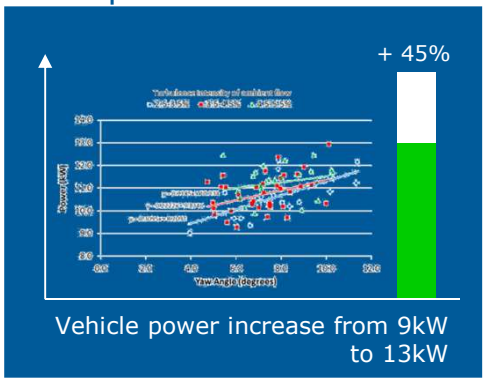


Wind:

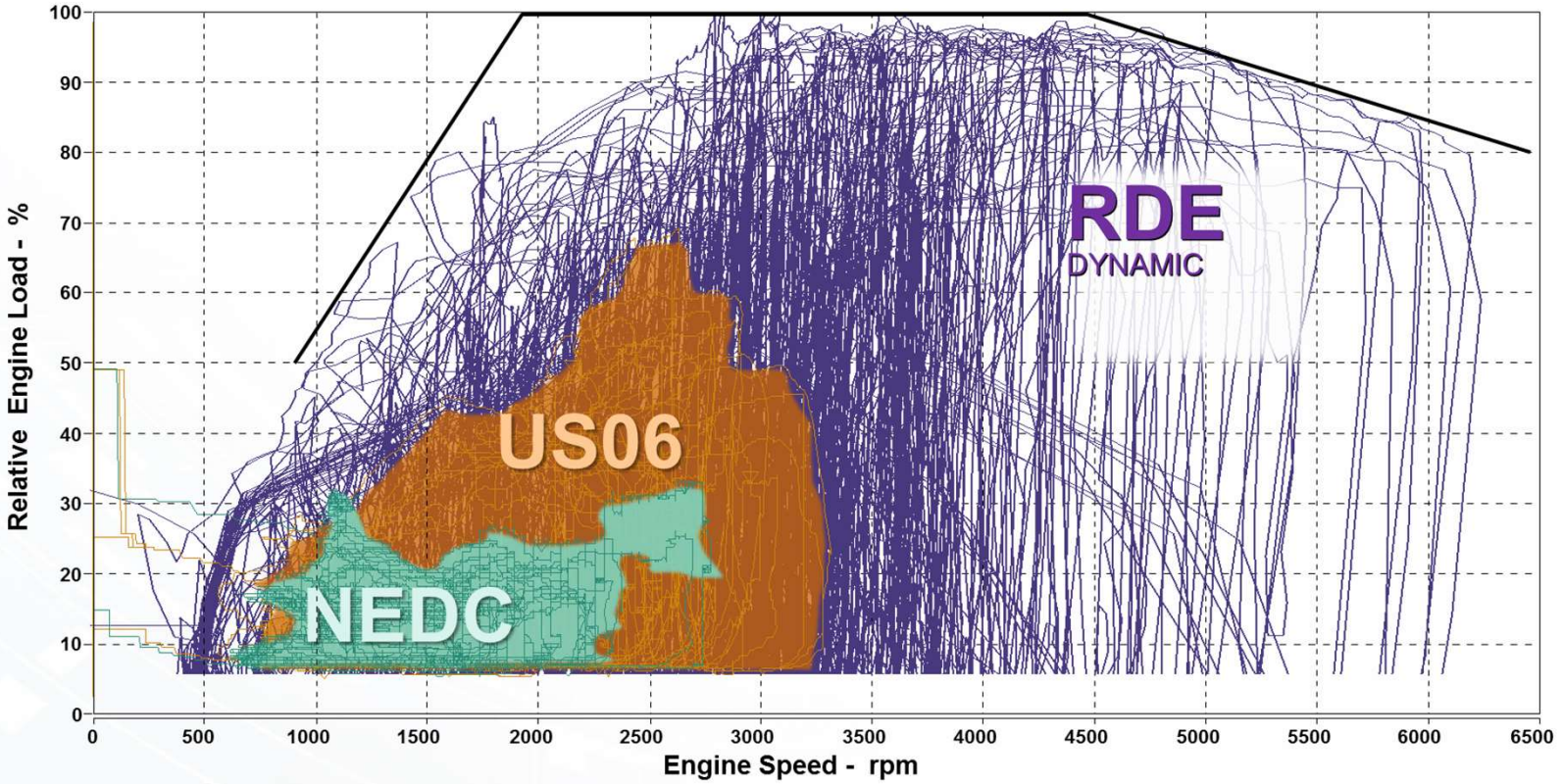
Impact of wind is:

- crosswind
- traffic turbulences
- drafting (Windschatten)

Example:



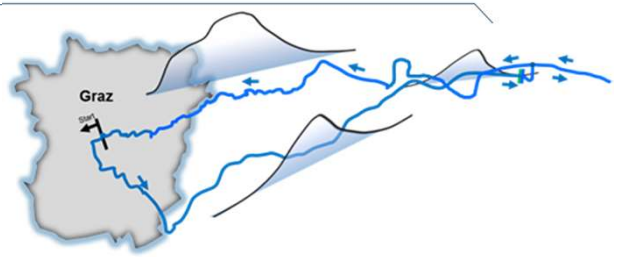
Impact of drive Cycles



Vehicles must be clean in a much larger area of the engine map:

- NEDC → WLTC
- Real Driving Emissions
- especially for down-sized engine concepts

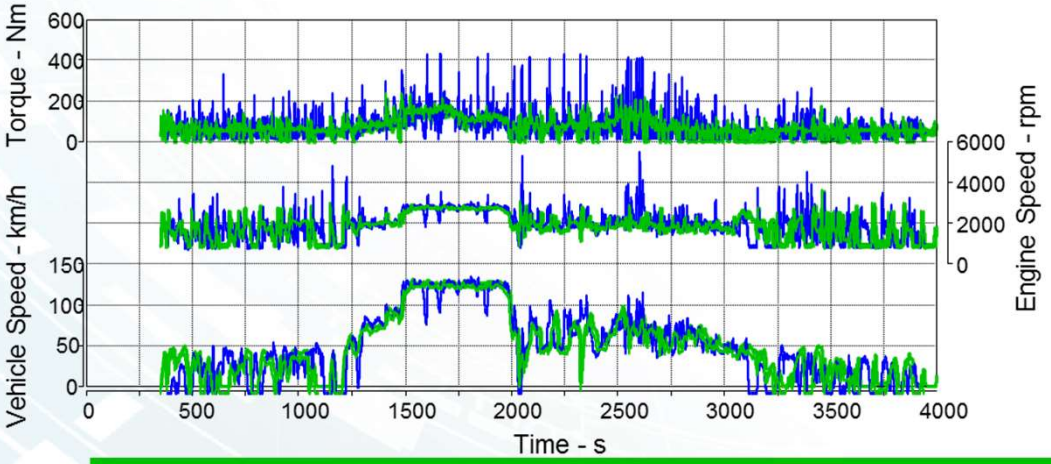
Impact of driving style

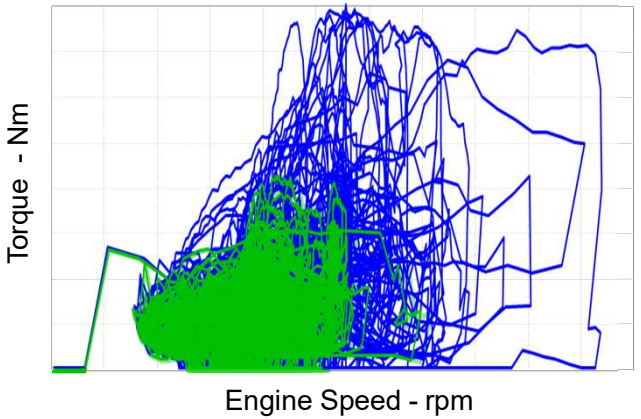


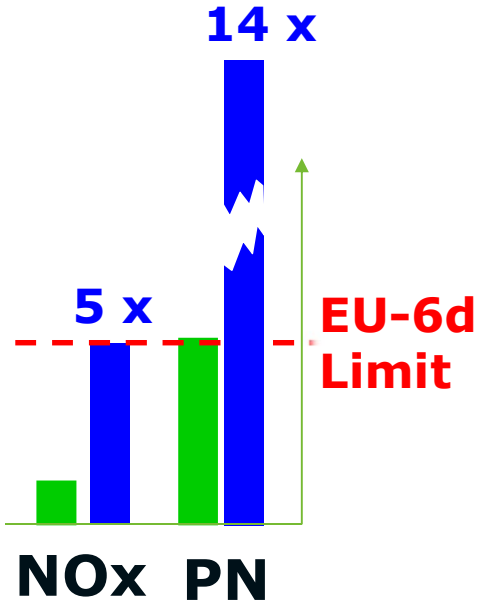
Impact of driving style in the AVL Graz RDE route on

- Drive dynamic
- Engine map
- Emissions

Dynamic Driving Style



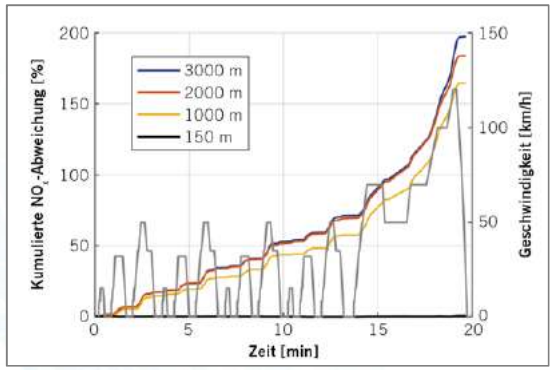


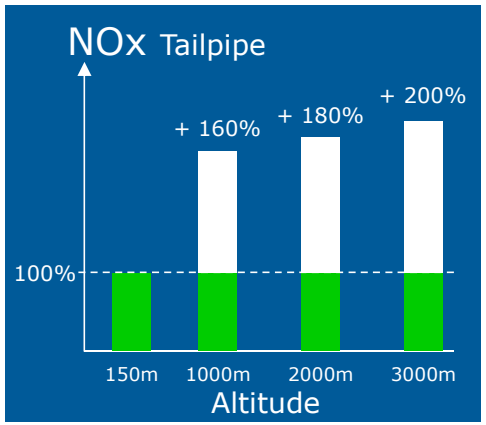


Moderate Driving Style

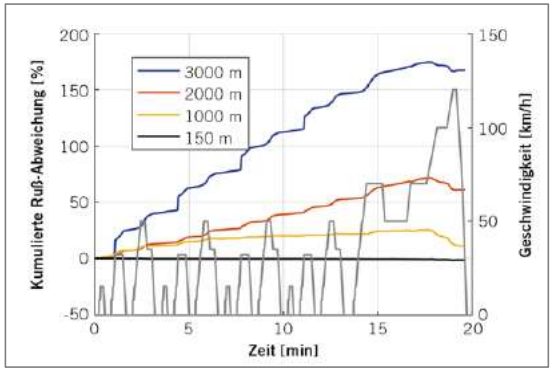
Impact of Altitude

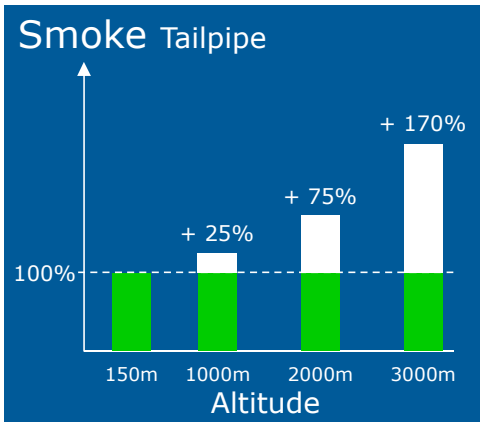
NOx



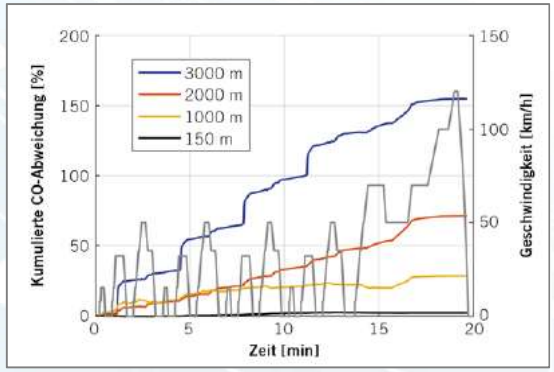


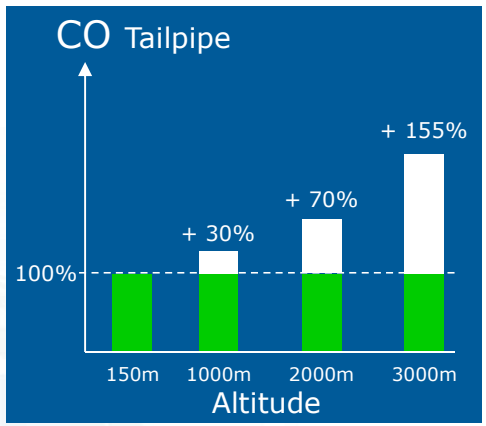
Smoke



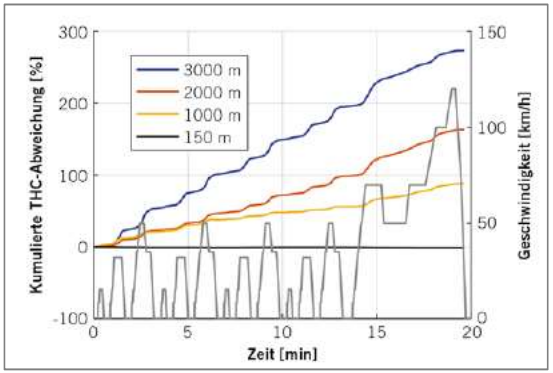


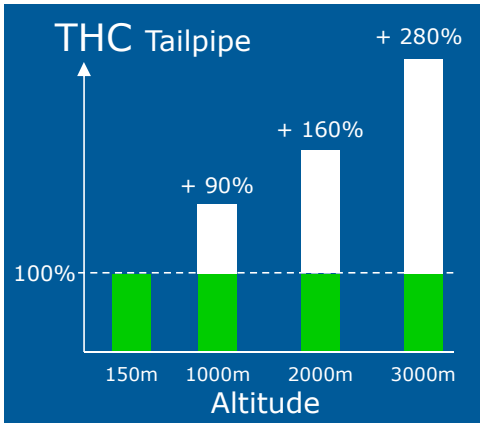
CO





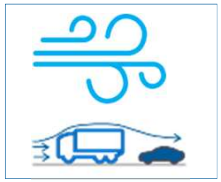
THC

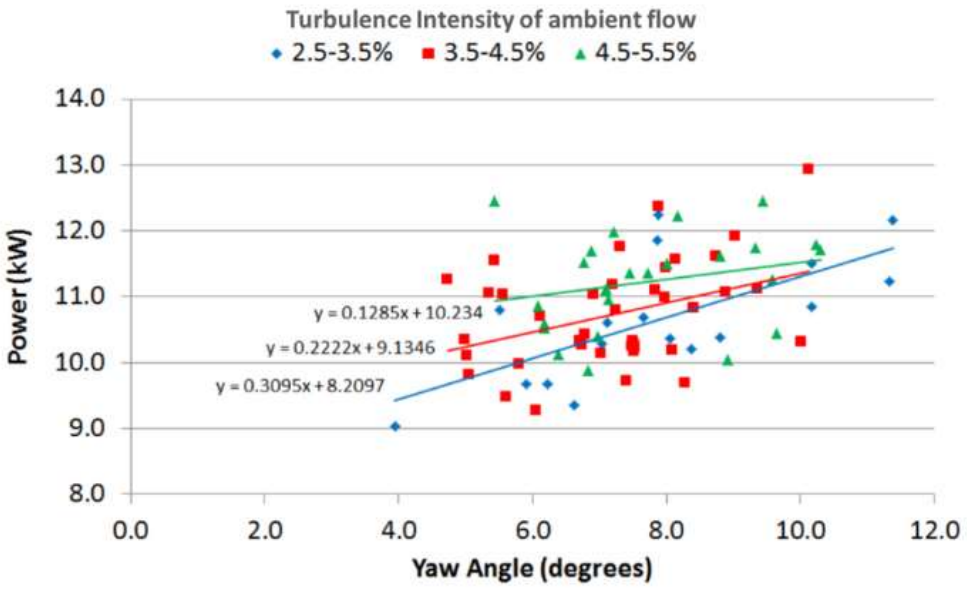




Source: MTZ 2016, Universitat Politècnica de València Spain, "Der Einfluss von Höhe auf die Emissionsmessung"

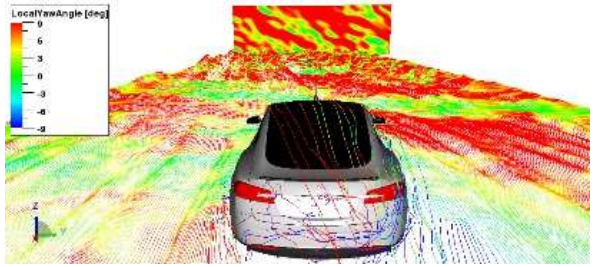
Impact of Wind

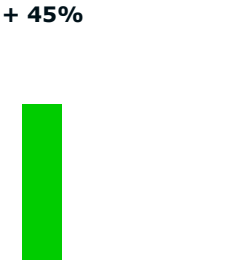




Impact of Wind:
For a typical **car driving at highway speeds**, **about 50% of the energy is spent overcoming aerodynamic drag**.

In the recent SAE paper (SAE 2015-01-1551), experimental on road measurements were gathered by comparing the energy consumption of the vehicle with the characteristics of the on road flow field, including traffic turbulence and crosswind, as measured by a pitot-static probe mounted on the roof of the vehicle.
The fluctuations in the measured wind are attributed mainly to turbulence caused by other vehicles on the road, while the measured yaw angle is attributed mainly to the prevailing crosswind and large-scale wind gusts.

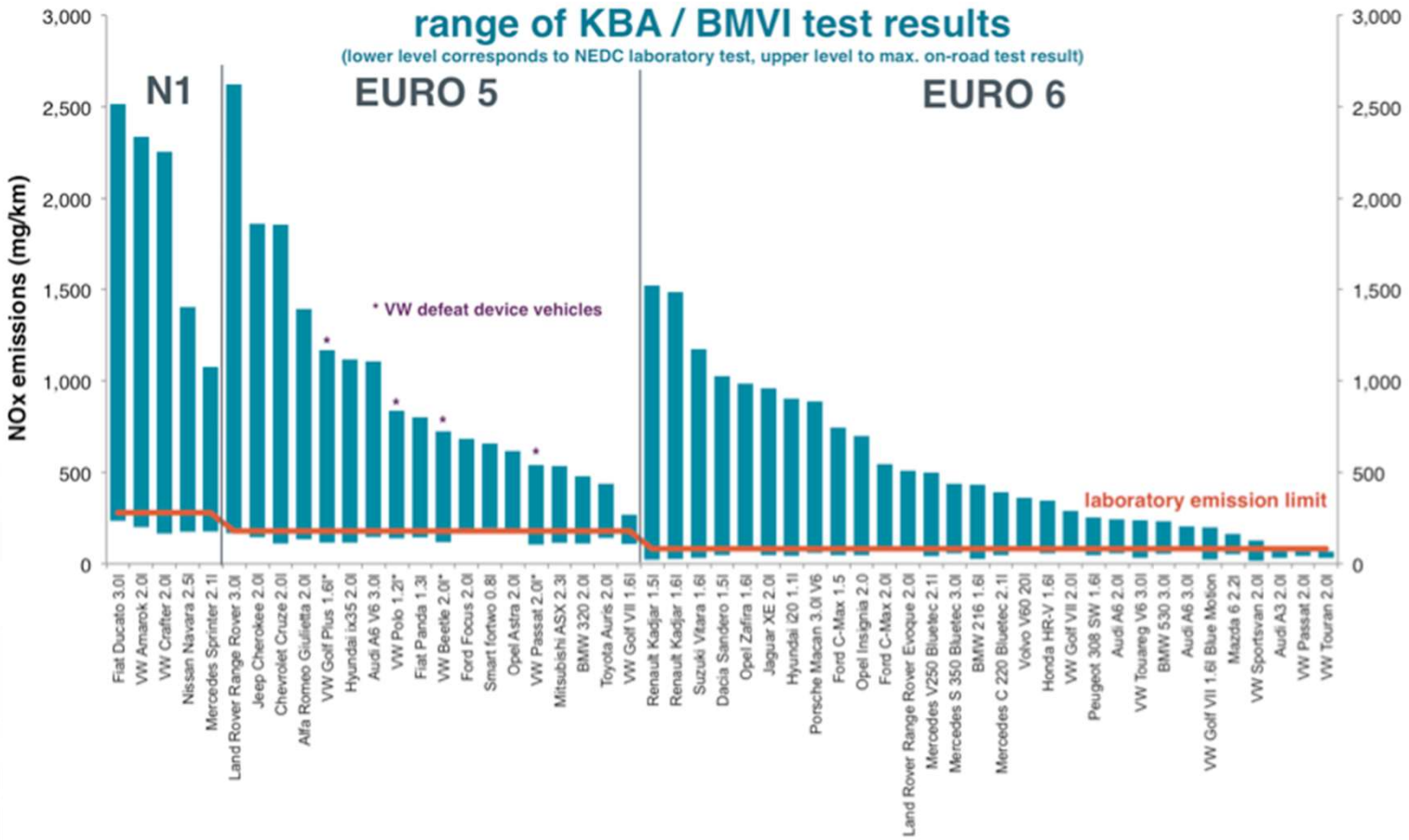




Vehicle power increase from 9kW to 13kW

Source: http://www.automotivetestingtechnologyinternational.com/articles.php?ArticleID=2031: Exa Corporation, Simulating 'realistic wind' further information SAE 2015-01-1551

ON-ROAD TEST RESULTS
GERMAN MINISTRY OF TRANSPORT



Source: Overview of the laboratory and on-road test results of the vehicle testing program by the German Ministry for Transport

RDE IMPLEMENTATION WORLDWIDE

New: **RDE 4** voted on 3.5.2018
In force 1.1.2019

EU:
Monitoring: 04/2016
Conformity factors: 09/2017

South Korea:
09/2017 (diesel only)

Japan:
2022 CF 2 (diesel only)

Low Speeds

USA (CARB):
PEMS for detection of defeat devices

China: China 6
Monitoring from 07/2020
CFs from 07/2023

Up to 2.400m

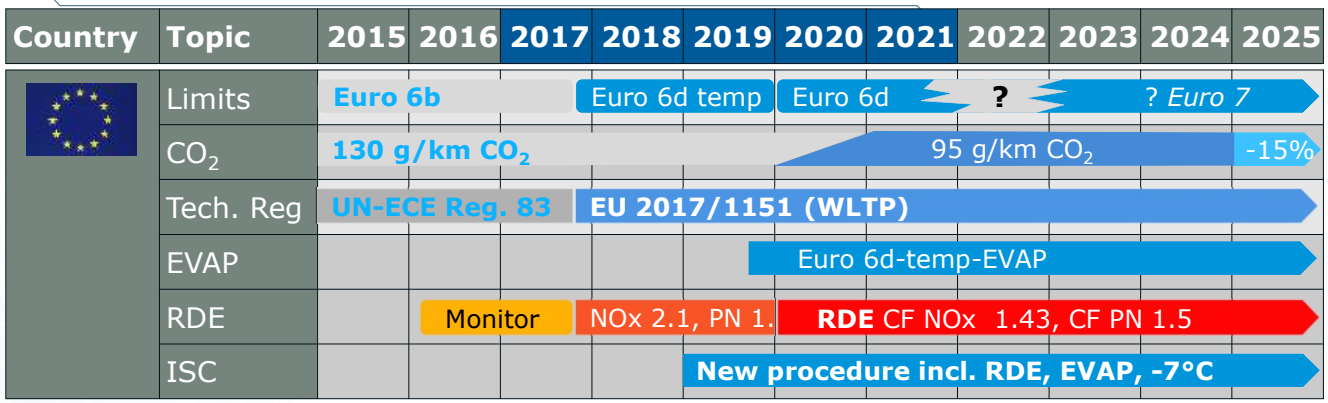
Brazil: draft PROCONVE L7, L8
Procedure to be published by 2020.
2022: monitoring?
2024/2027: CFs?

+ THC limit?

India: BS VI
04/2020: monitoring
04/2023: CFs

Low Speed & over 40°C

New characteristic of legislative development



- 04/2016 RDE Monitoring
- 09/2017 WLTP + RDE with CF-temp.
- **01/2019 New ISC Procedure**
- 09/2019 New EVAP Procedure
- 01/2020 RDE with final CF

No lead time for engineering / Last-Minute amendments

May 2018 RDE Package 4
- In Service Conformity, Member State Surveillance

3Q 2017 revised evaporative emission testing
- Canister aging, test procedures, sealed tank systems for hybrids, ...

Jan. 2017 Guidance on AES and Defeat Devices
- Documentation of AES, engine protection, impact assessment, defeat device testing, ...

Dec. 2016 RDE Package 3
- PN Limit, Cold start, Hybrids

Feb. 2016 RDE Package 2
- NOx Limit, Test Boundary Conditions

2015 RDE Package 1
- Decision on PEMS, Monitoring from 2016

EU – NEW - Update RDE Package 4 (Vote)

Corrections, clarifications, provisions for LCVs

CLEAR not used anymore, EMROAD only for trip normality

New emissions calculation method

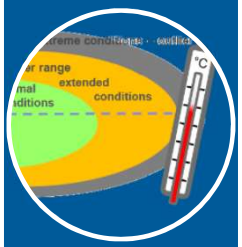
Reduced NO_x margin

In-service conformity requirements added

Trip requirements

Urban, rural, motorway –

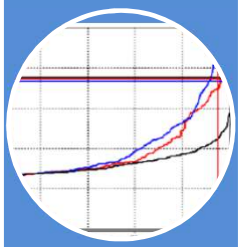
Min. and max. speed



Non-dynamic boundary conditions

Temperature

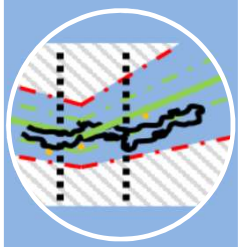
Altitude



Dynamic boundary conditions

v*apos

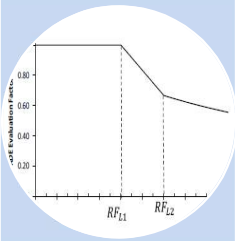
RPA



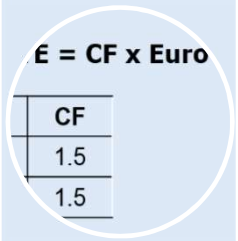
Trip normality, ~~weighting~~

EMROAD

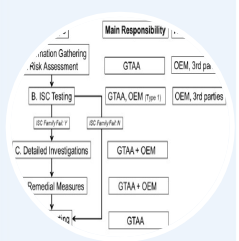
~~CLEAR~~



Calculation of final RDE emission results



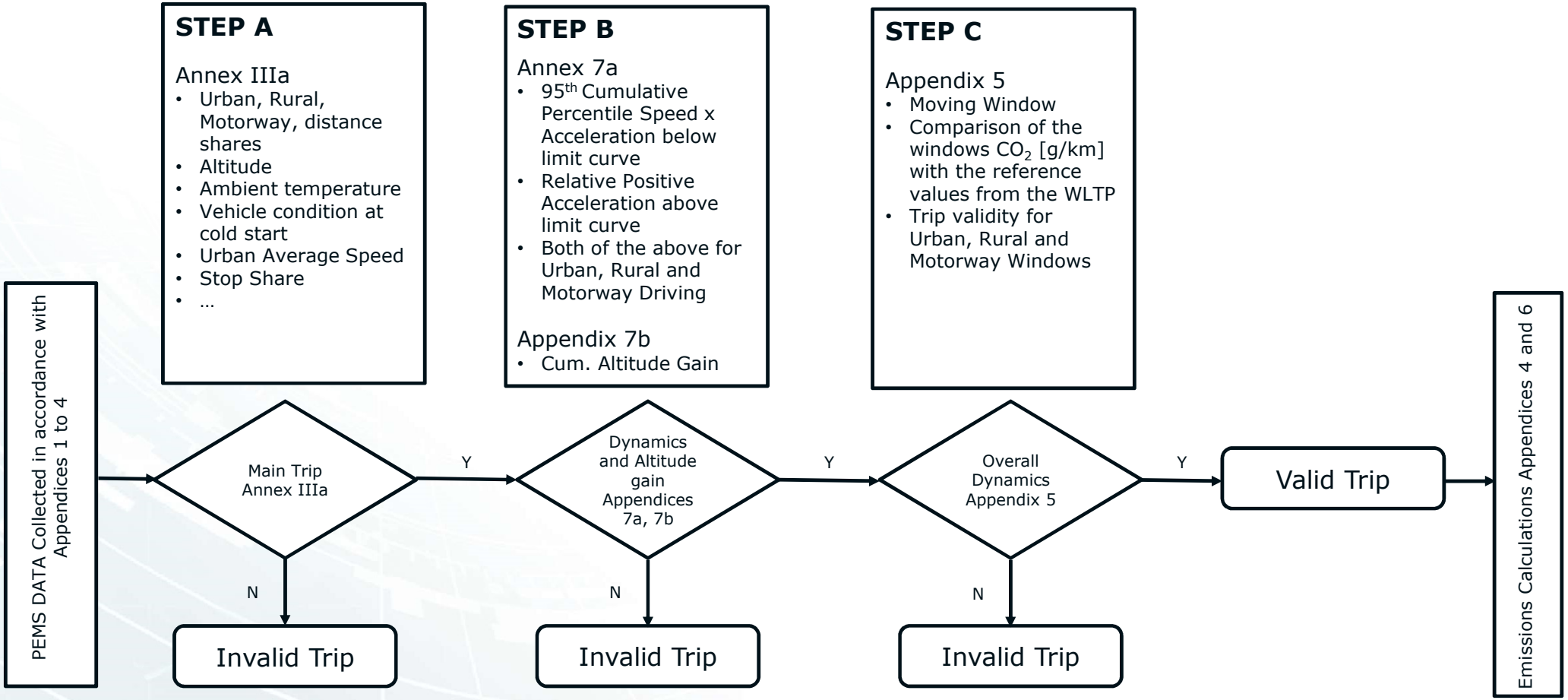
Comparison of final emission results with limit



In-service conformity testing

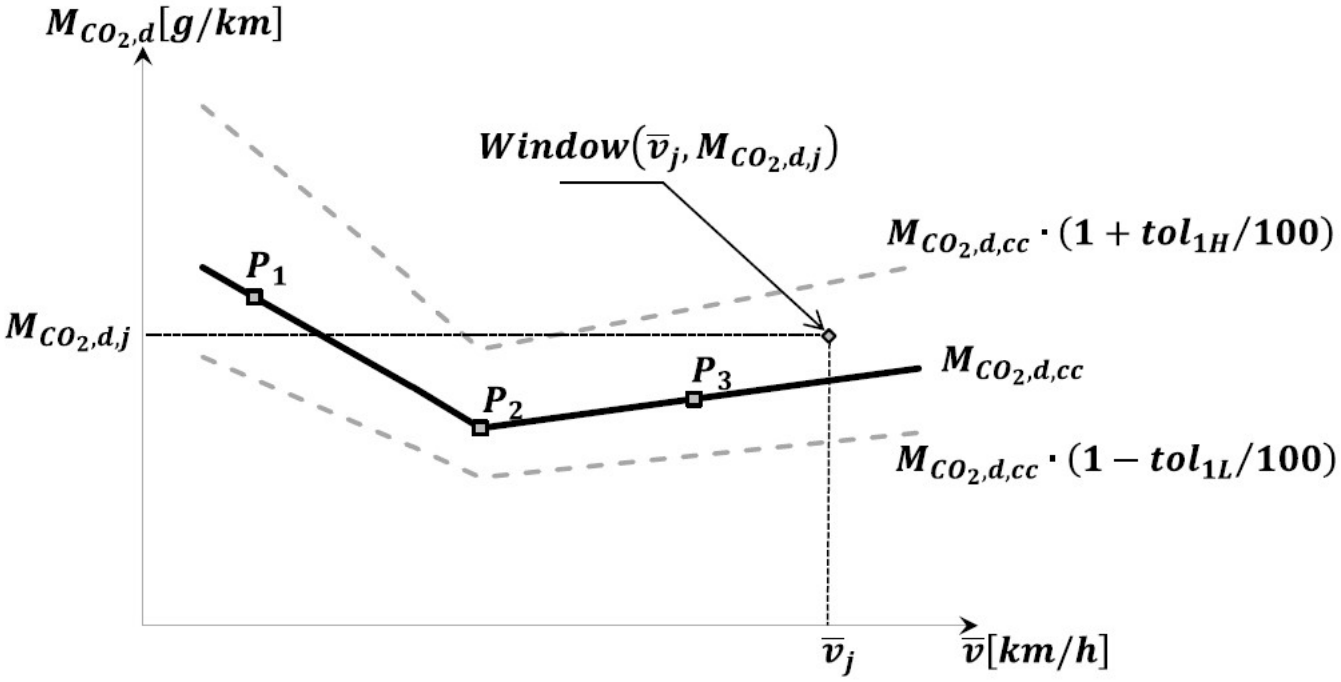
Assessment of trip validity

9.2. The trip validity shall be verified in a three-step procedure as follows:



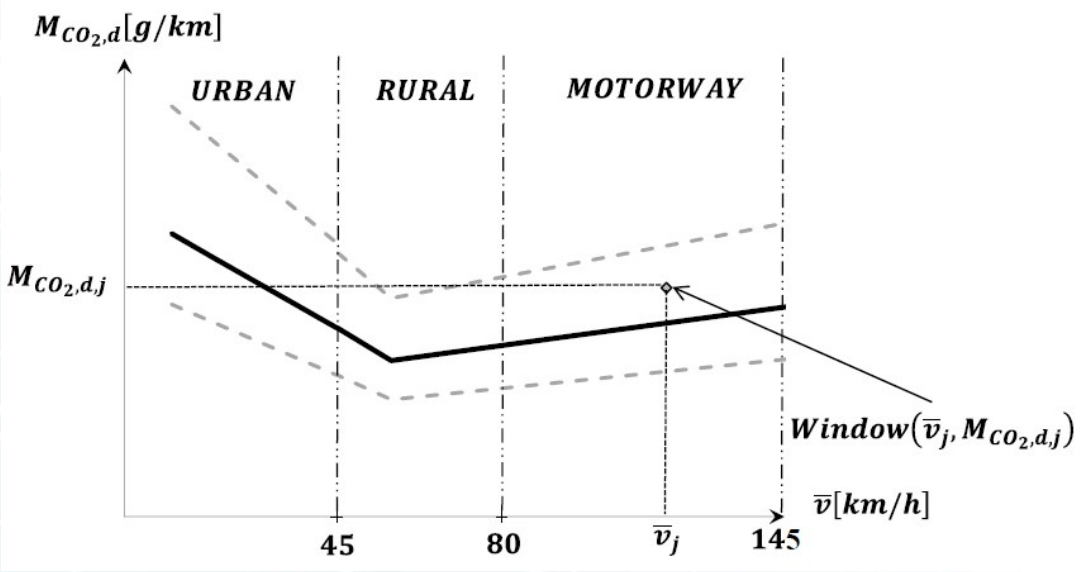
Step C: Appendix 5 – Verification of overall trip dynamics using the MAW method (I)

- Offset for P1, P2, P3 removed
  - P1: v=18.882 km/h, CO_2 emissions over WLTP low speed phase
  - P2: v=56.664 km/h, CO_2 emissions over WLTP high speed phase
  - P3: v= 91.997 km/h, CO_2 emissions over WLTP extra high speed phase

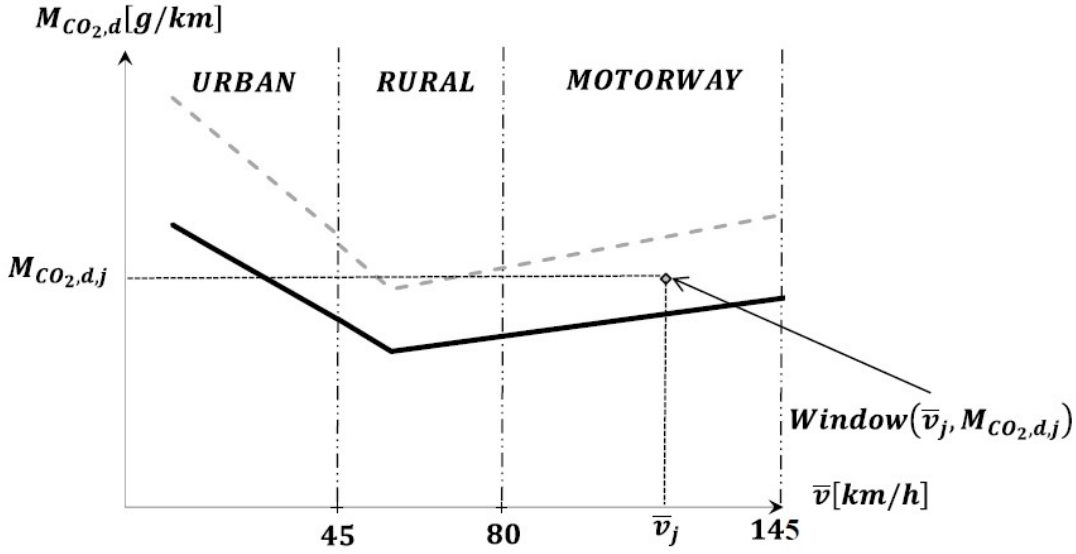


Step C: Appendix 5 – Verification of overall trip dynamics using the MAW method (I)

- Tol_{1high} = 45% for urban, 40% for rural and motorway driving
- Tol_{1low} = 25% for ICE and NOVC-HEV, 100% for OVC-HEV
- Validity criteria:
  - 50% of windows within tolerances.
  - For NOVC-HEV: tol_{1high} can be extended to 50%.



CO_2 characteristic curve and tolerances for ICE and NOVC-HEV



CO_2 characteristic curve and tolerances for OVC-HEV

Appendix 7c (evaluation for OVC-HEV)

Appendix 7c (evaluation procedure for OVC-HEV) is deleted.

Evaluation of trip validity for OVC-HEV is included in Appendix 5 (MAW method)

Emissions calculation method is included in Appendix 6 (new emissions calculation method)

New Appendix 6 – Calculation of the final RDE emissions results – ICE and NOVC-HEV

For valid trips, the final RDE results are calculated as follows (k = t for total trip, u for urban part):

$$M_{RDE,k} = m_{RDE,k} * RF_k$$

Index (k) refers to the category (t=total, u=urban, 1-2=first two phases of the WLTP cycle)

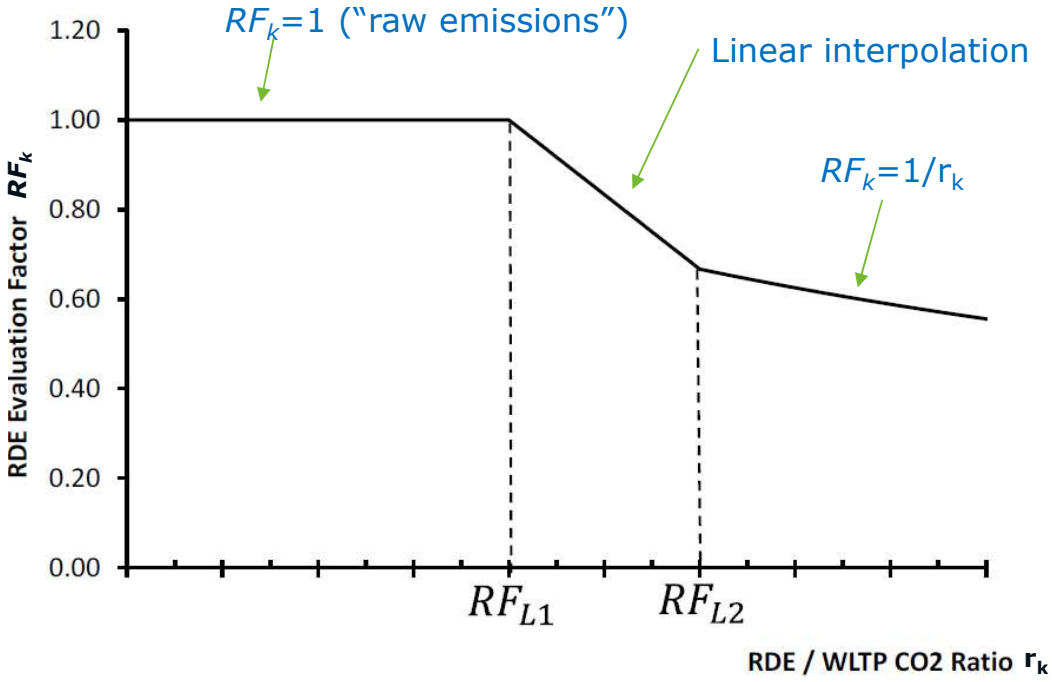
$m_{RDE,k}$ … pollutant emissions during RDE trip in [mg/km] or [#/km]

RF_k ….. RDE Evaluation Factor

$M_{RDE,k}$….. Final RDE result [mg/km] or [#/km]

Value of RF_k is dependent on ratio of CO_2 emissions [g/km] during RDE trip to CO_2 emissions during WLTP

$$r_k = \frac{M_{CO_2,RDE,k}}{M_{CO_2,WLTP,k}}$$



For type approvals before 01.01.2020:

RF_{L1} = 1.20 and RF_{L2} = 1.25

For type approvals from 01.01.2020:

RF_{L1} = 1.30 and RF_{L2} = 1.50

New Appendix 6 – Calculation of the final RDE emissions results – OVC-HEV

For valid trips, the final RDE results are calculated as follows (For either the urban or the total driving):

$$M_{RDE,k} = m_{RDE,k} * RF_k$$

Index (k) refers to the category (t=total, u=urban, 1-2=first two phases of the WLTP cycle)

$m_{RDE,k}$ … pollutant emissions during RDE trip in [mg/km] or [#/km]

RF_k ….. RDE Evaluation Factor

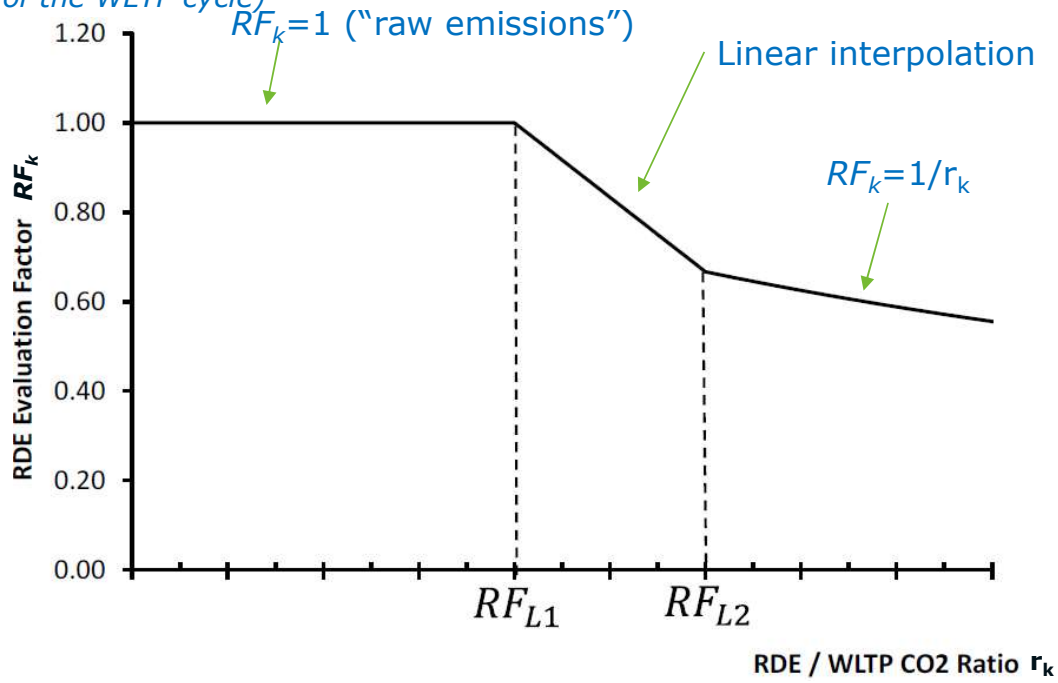
$M_{RDE,k}$….. Final RDE result [mg/km] or [#/km]

Value of RF_k is dependent on ratio of CO_2 emissions [g/km] during RDE trip to CO_2 emissions during WLTP (charge sustaining mode)

$$r_k = \frac{M_{CO_2,RDE,k}}{M_{CO_2,WLTP-CS,t}} * \frac{0.85}{IC_k}$$

$$IC_k = \frac{d_{ICE,k}}{d_{ICE,k} + d_{EV,k}}$$

$d_{ICE,k}$ … Distance driven [km] with ICE on for OVC-HEV during RDE
$d_{EV,k}$ … Distance driven [km] with ICE off for OVC-HEV during RDE



For type approvals before 01.01.2020: RF_{L1} = 1.20 and RF_{L2} = 1.25
For type approvals from 01.01.2020: RF_{L1} = 1.30 and RF_{L2} = 1.50

Not-to-exceed limits, conformity factors

Throughout its normal life the emissions of a vehicle type emitted at a RDE test shall not be higher than the following not-to-exceed (NTE) values:

$$NTE_{pollutant} = CF_{pollutant} \times \sout{TF(p_1,\ldots p_n)} \times EURO\text{-}6$$

Pollutant	NO_x	PN	CO^1	THC	$THC+NO_x$
$CF_{pollutant}$	**2.1**	**1 + *margin PN* with *margin PN* = 0.5**	-	-	-
Pollutant	NO_x	PN	CO^1	THC	$THC+NO_x$
$CF_{pollutant}$	**1 + *margin* NO_x with *margin* NO_x = 0.43**	**1 + *margin PN* with *margin PN* = 0.5**	-	-	-

Final CF PN (from 09/2017)

Temporary CF NO_x (from 09/2017)

Euro 6d-TEMP

Final CF NO_x (from 01/2020)

Euro 6d

[1]CO emissions shall be measured and recorded at RDE test

"margin" is a parameter taking into account the additional measurement uncertainties introduced by the PEMS equipment, which are subject to an annual review and shall be revised as a result of the improved quality of the PEMS procedure or technical progress.

NTE requirements shall be fulfilled for the **urban part** and **the complete PEMS trip**.

AVL Solutions

(A comprehensive approach to RDE)

AVL M.O.V.E

The Industry Standard to Measure Real Driving Emissions (RDE)

COMPLETE RDE TEST SYSTEM

AVL M.O.V.E iS System

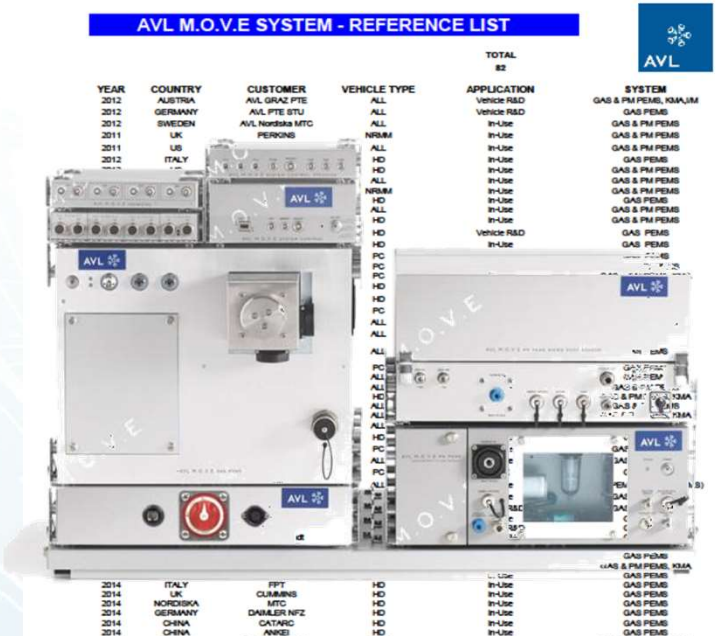
- GAS PEMS iS
- PN PEMS iS
- EFM iS
- System Control
- Concerto 5™ - M.O.V.E Data Toolbox

… done more than 40.000 RDE tests @ 100+ customers with 300+ systems!

AVL M.O.V.E iS

The Industry Standard to Measure Real Driving Emissions (RDE)

AVL M.O.V.E MARKET LEADER SHIP CUSTOMER REFERENCES



AVL GAS PEMS 140+
AVL PM PEMS 120+

AVL GAS PEMS iS 300+
AVL PN PEMS iS 230+

AVL M.O.V.E – RDE TESTING SYSTEM

GAS PEMS iS

CO, CO2, NO, NO2, O2

PN PEMS

Particle Number

AVL M.O.V.E EFM

Exhaust Mass Flow

AVL PLUtron™

Fuel Flow

AVL Indimicro

Voltage/ amps

GPS

T, p, %

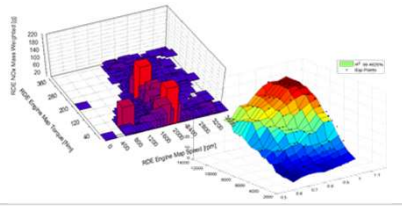
SYSTEM CONTROL

OBD II

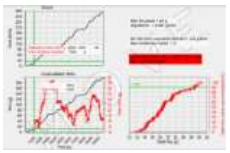
Online Tools

MOVE Data Toolbox

Advanced Analysis Tools



Reporting



Road-2-Lab Solution

RDE Testing

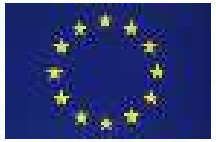
RDE Development

M.O.V.E – an In-Vehicle test platform which is aligned with the In-Lab test platform

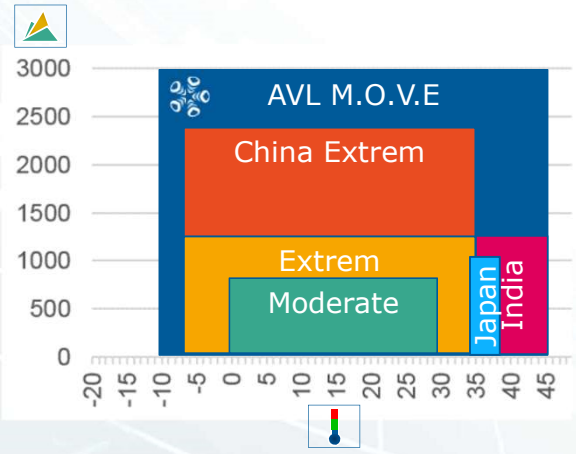
RDE TEST REQUIREMENTS

Application

Standard



Real Driving Emissions (2016/427 1st package, 2016/646 2nd package, 2017/1151 3rd package, 4th package)



Light duty vehicle on Real Driving Emission testing:

- Portable E
  PN, Exhau
- Implementation: EU 2017, Korea 2018, China 2019, India 2020, Japan 2022

randomness of real driving

Limits:

- CF NOx:
- 1 calculation method for all types – focusing on raw emissions

low emissions under all conditions

RDE Test requirements:

- 30min con
- RDE Drive
- 34% Urban (<60km/h), 33% Rural (60 ... 90km/h), 33% Motorway (>90km/h)
- max. Speed 145km/h (can be extended to 160km/h on test track)
- positive altitude gain < 1200m/100km
- OVC Hybrid test in Charge–Sustaining mode
- Periodical Regeneration w/o Regeneration use ki-factors

realistic testing will be tough to meet requirements

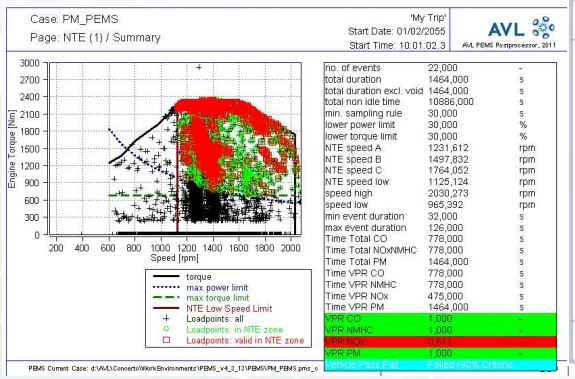
Ambient conditions:

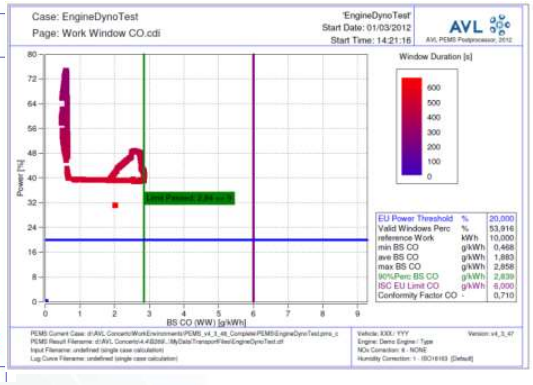
- 0°C to 30
- up to 700

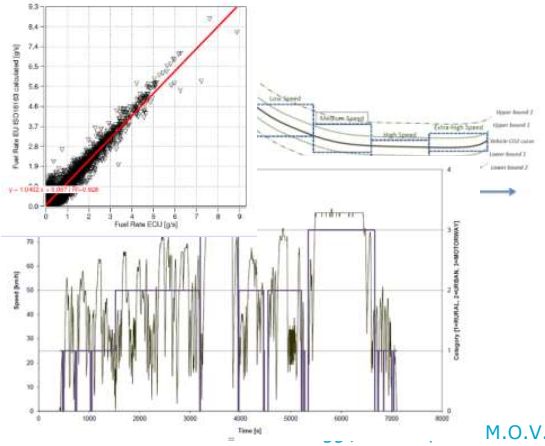
wide range of environmental conditions

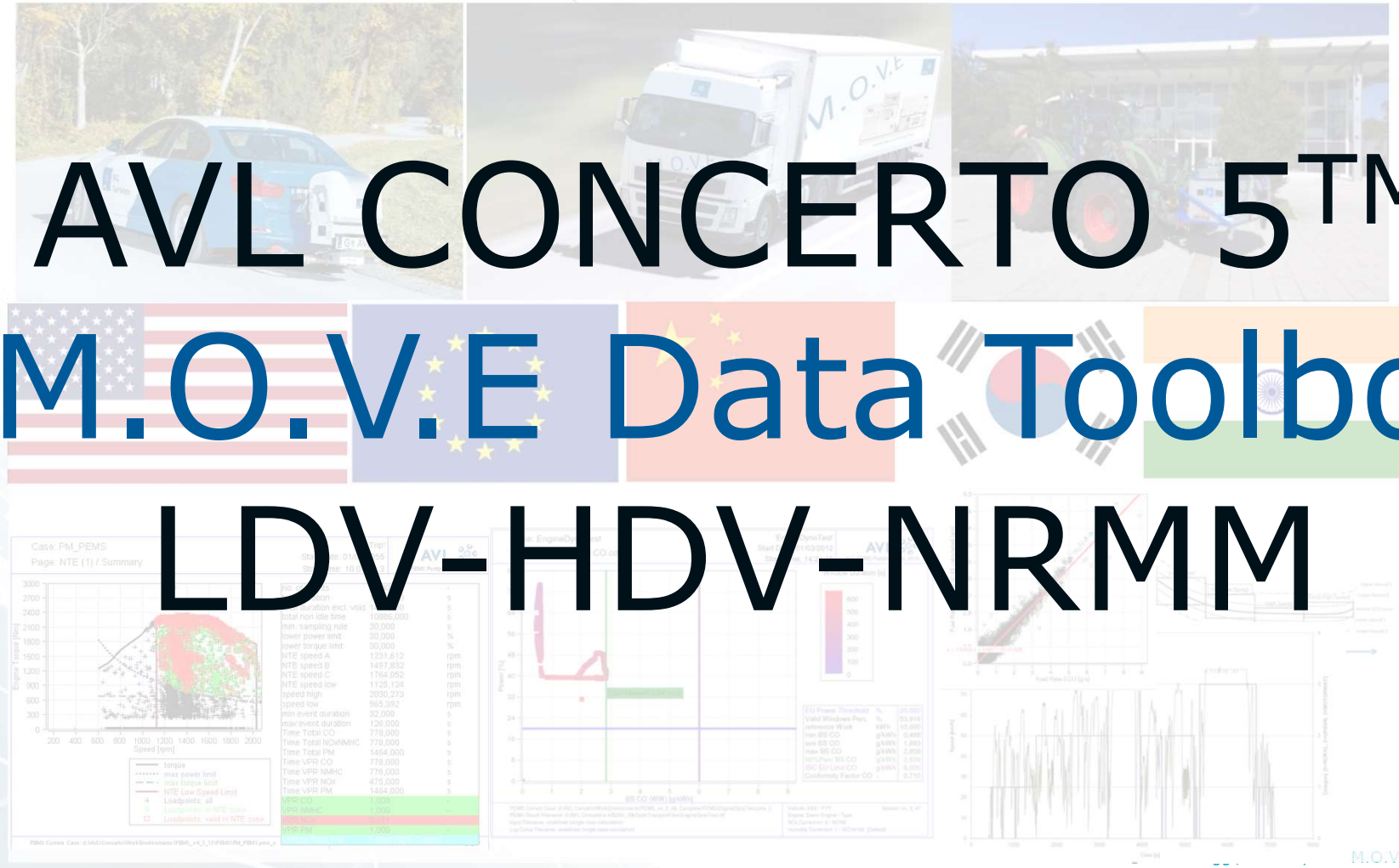

AVL
HOW TO GET A VALID TEST?
TRIP REQUIREMENTS…
KEY IS POST PROCESSING!!!

AVL CONCERTO 5™ - M.O.V.E DATA TOOLBOX LEGISLATIVE POST PROCESSING







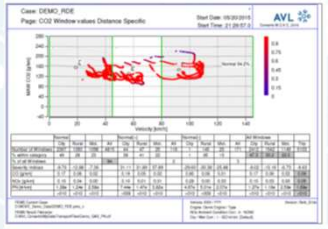


AVL CONCERTO 5™

M.O.V.E Data Toolbox

LDV-HDV-NRMM

AVL CONCERTO 5™ - M.O.V.E DATA TOOLBOX
Example LDV - RDE 3 Results



NEW: Quick View

Case: RDE_Demo_Data
Page: Conformity Factors

'Huntington Beach'
Start Date: 02/10/2016
Start Time: 11:16:28.0

AVL Concerto M.O.V.E. 2016

CALIBRATION TRIP DYNAMICS EMROAD CLEAR

Unweighted Results			
		Avg. Trip	Limit
NOx	g/km	0.0068	0.800
CO	g/km	0.5667	0.500
CO2	g/km	127.9111	
PN	#/km	****	6.000e+011

JRC						
		Trip	Conformity Factor			
			City	Rural	Motorway	Trip
NOx	g/km	0.0068	0.01	0.01	0.01	0.01
CO	g/km	0.3998	0.30	0.25	1.91	0.80
PN	#/km	0.000e+000	0.00	0.00	0.00	0.00

CLEAR						
NOx	g/km	0.0070	0.01	0.01	0.01	0.01
CO	g/km	0.4756	0.27	0.47	2.11	0.95
PN	#/km	0.000e+000	0.00	0.00	0.00	0.00

RDE TÜV Certified!

TÜV Certified
For correct legislative implementation

<u>TÜV certificate:</u>

- HD (EU) No. 582/2011 Annex II and (EU) No. 64/2012

- RDE Package 1 – 2016/427
- RDE Package 2 – 2016/646

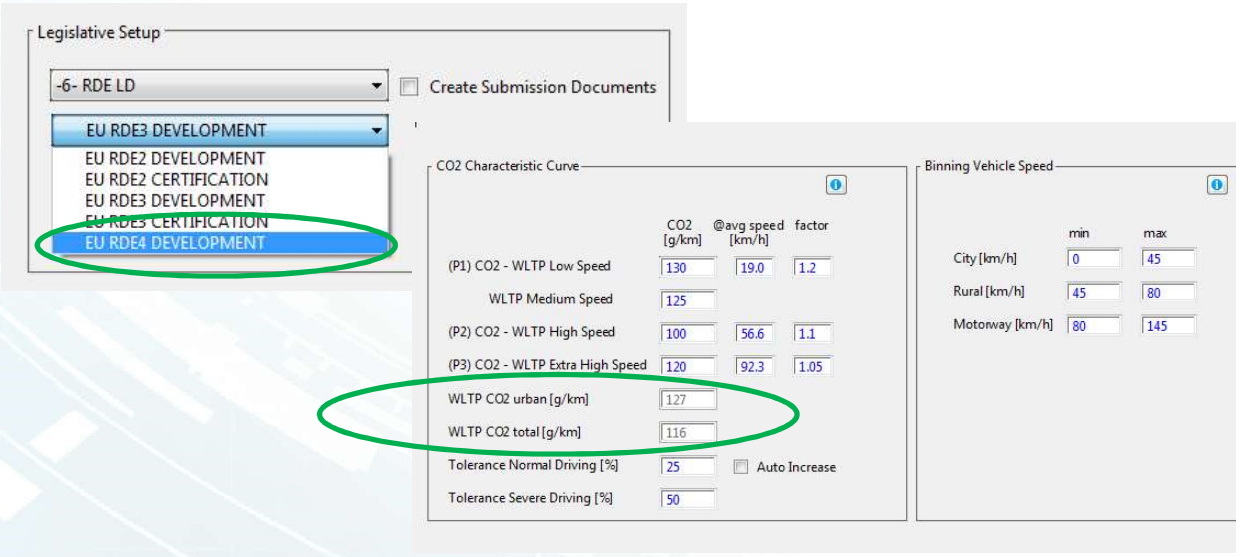
- RDE Package 3 - 2017/1154

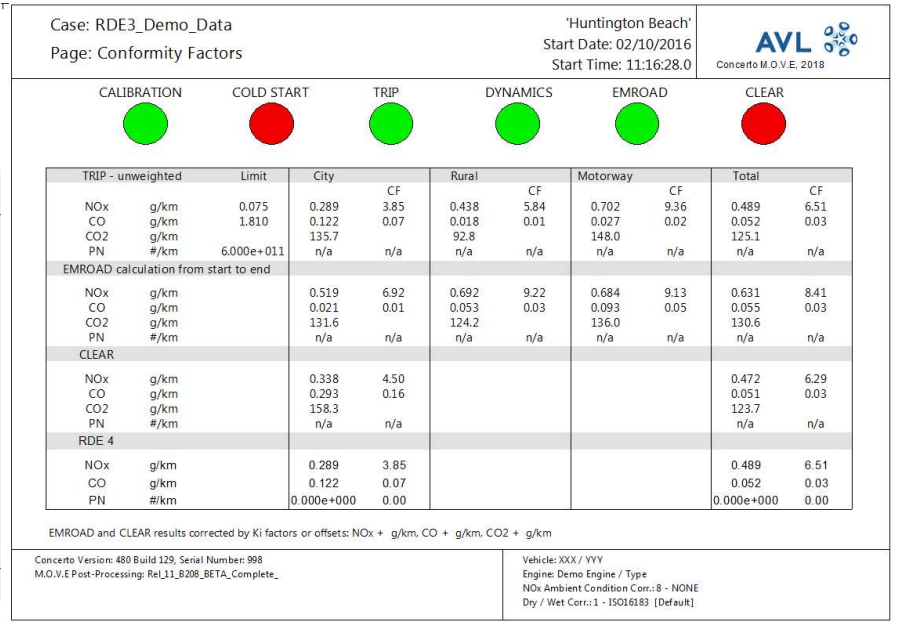
AVL CONCERTO 5™ - M.O.V.E DATA TOOLBOX
RDE 4 Implementation coming soon

NEW

SW Release - RDE 4 Implementation Plan:

- End of July 2018 – Final Vote implemented as „EU RDE4 development mode“
- End of 2018 – EU RDE 4 certification mode available





MOVE Software Subscription Customers will receive it automatically!

Further Applications

AVL M.O.V.E In-Vehicle Testing

Emission Measurement

Start of discussion about RDE

EU-4: 2016 based on UN-ECE-Regulation 40/47 and GTR-2

Introduction of PM limits for CI and GDI engines, only

EU-5: 2020 based on UN-ECE GTR-2

open discussion (Effect study) in-use conformity, off-cycle emissions and PN

USA: EPA Motorcycle Standard [g/km]

no change since 2010

USA: CARB Motorcycle Standard [g/km]

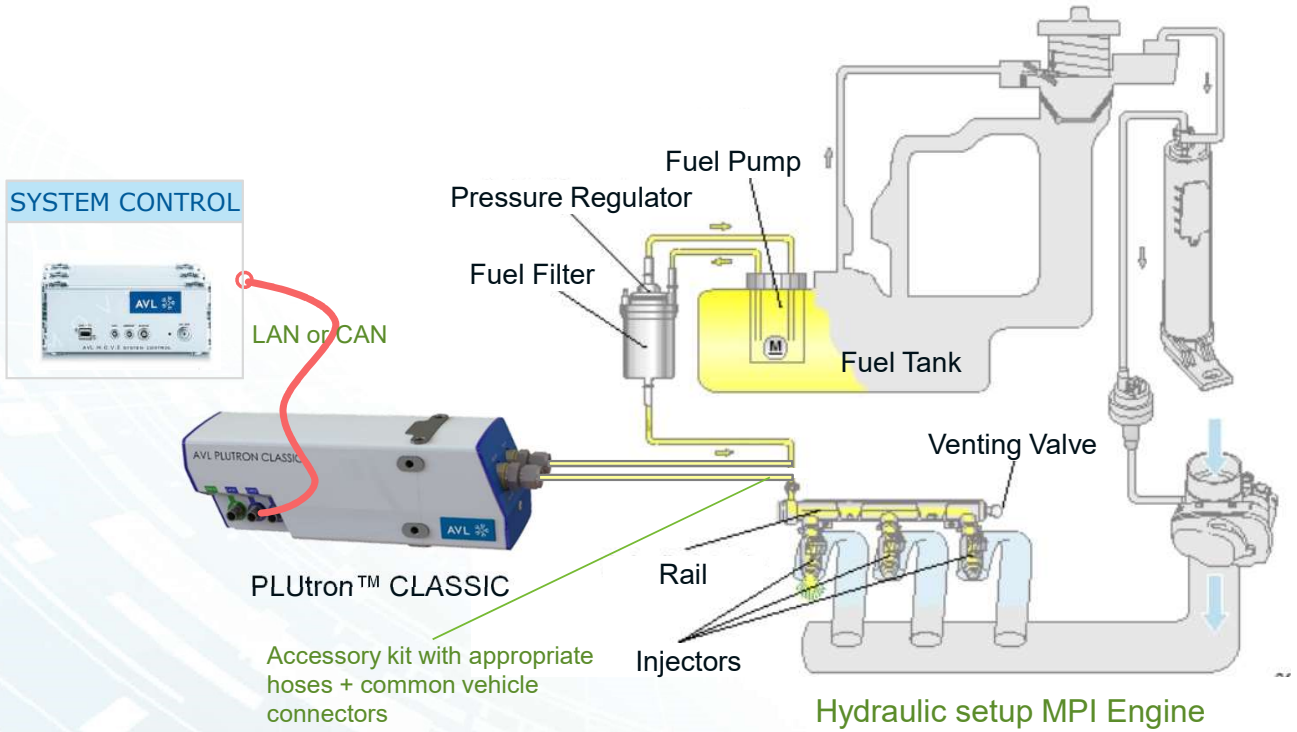
no change since 2008

Asia (India): still Leading the MC emission regulations

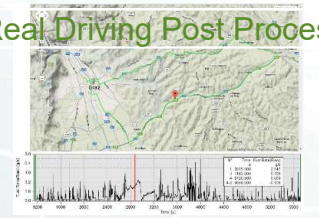
Is „Real Driving Emission“ Measurement on Motorcycles possible?

Case Study with TU Graz
Setup Motorcycle with actual RDE equipment

AVL M.O.V.E iS
CO2 Testing – Real Fuel Consumption



Real Driving Post Processing



- Fast connection to your on board fuel system
- Provides online result by l/km (also via MAP data)
- Full integration with AVL M.O.V.E and thus PEMS testing
- Highest accuracy for real driving fuel consumption at low flows

AVL M.O.V.E iS
RDE DEVELOPMENT – FUEL EXTENSION

GAS PEMS iS

CO, CO2, NO, NO2, O2

PN PEMS

Particle Number

AVL M.O.V.E EFM

Exhaust Mass Flow

AVL PLUtron™

Fuel Flow

GPS

T, p, %

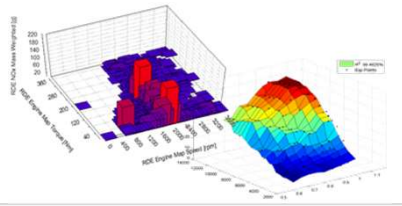
SYSTEM CONTROL

OBD II

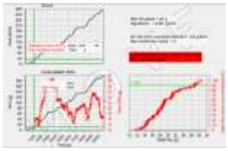
Online Tools

MOVE Data Toolbox

Advanced Analysis Tools



Reporting

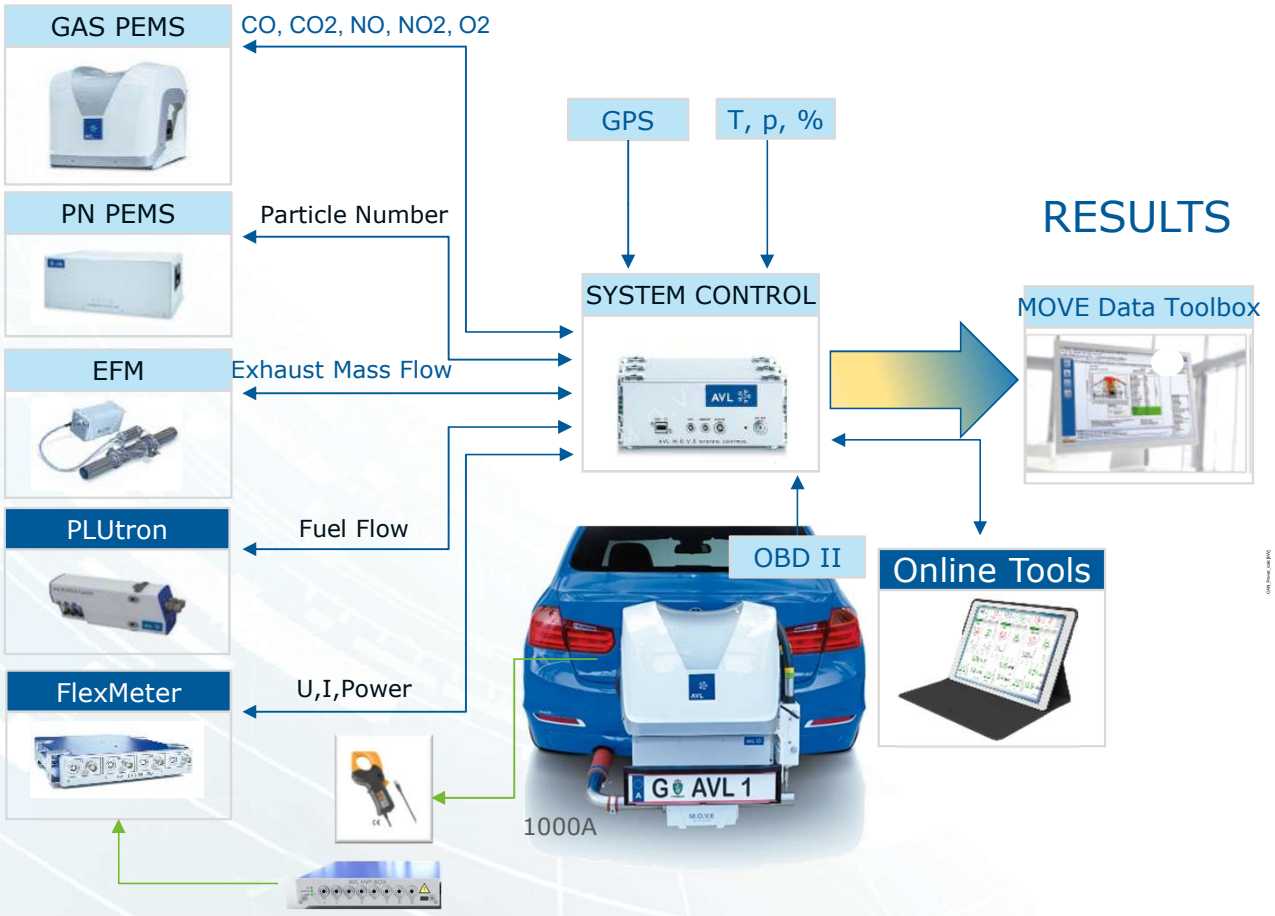


RDE Testing

RDE Development

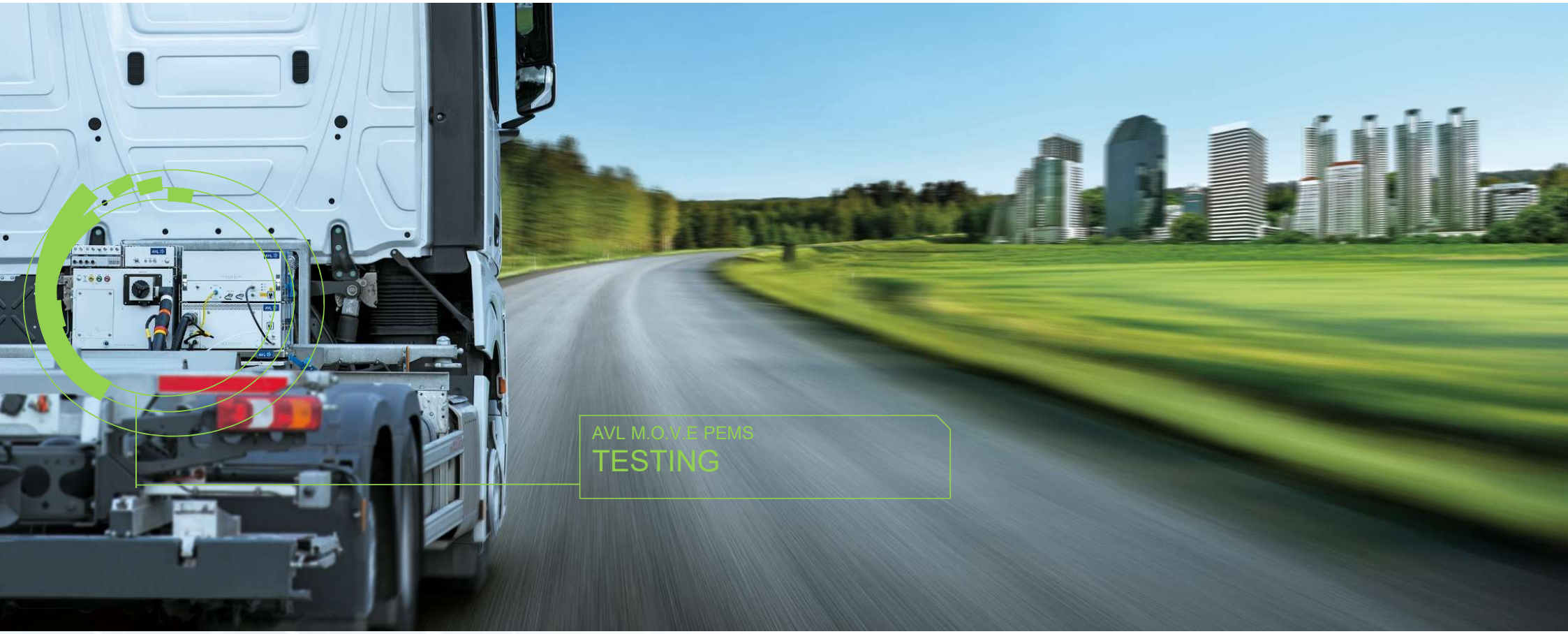
M.O.V.E – an In-Vehicle test platform which is aligned with the In-Lab test platform

AVL M.O.V.E - Energy Efficiency Evaluation CO2 & E-Power Measurement Extension



- **Easy add-on of hybrid key figures** into System Control (real fuel consumption, battery state of charge, Recuperated energy, charging modes, HCU information)
- High speed power measurement for exact **battery aging effects determination**
- Extended **Reporting of total energy efficiency** for better evaluation of vehicle strategy

AVL M.O.V.E HEAVY DUTY TESTING



Heavy duty in-service conformity with PEMS

USA and Canada

HDIUT –
In-use Testing with PEMS equipment and field-testing procedures 1 January 2005

EU

Euro VI: 1 January 2013 all new vehicle types

South Korea

Euro VI: PEMS requirements from 1 January 2016

Japan

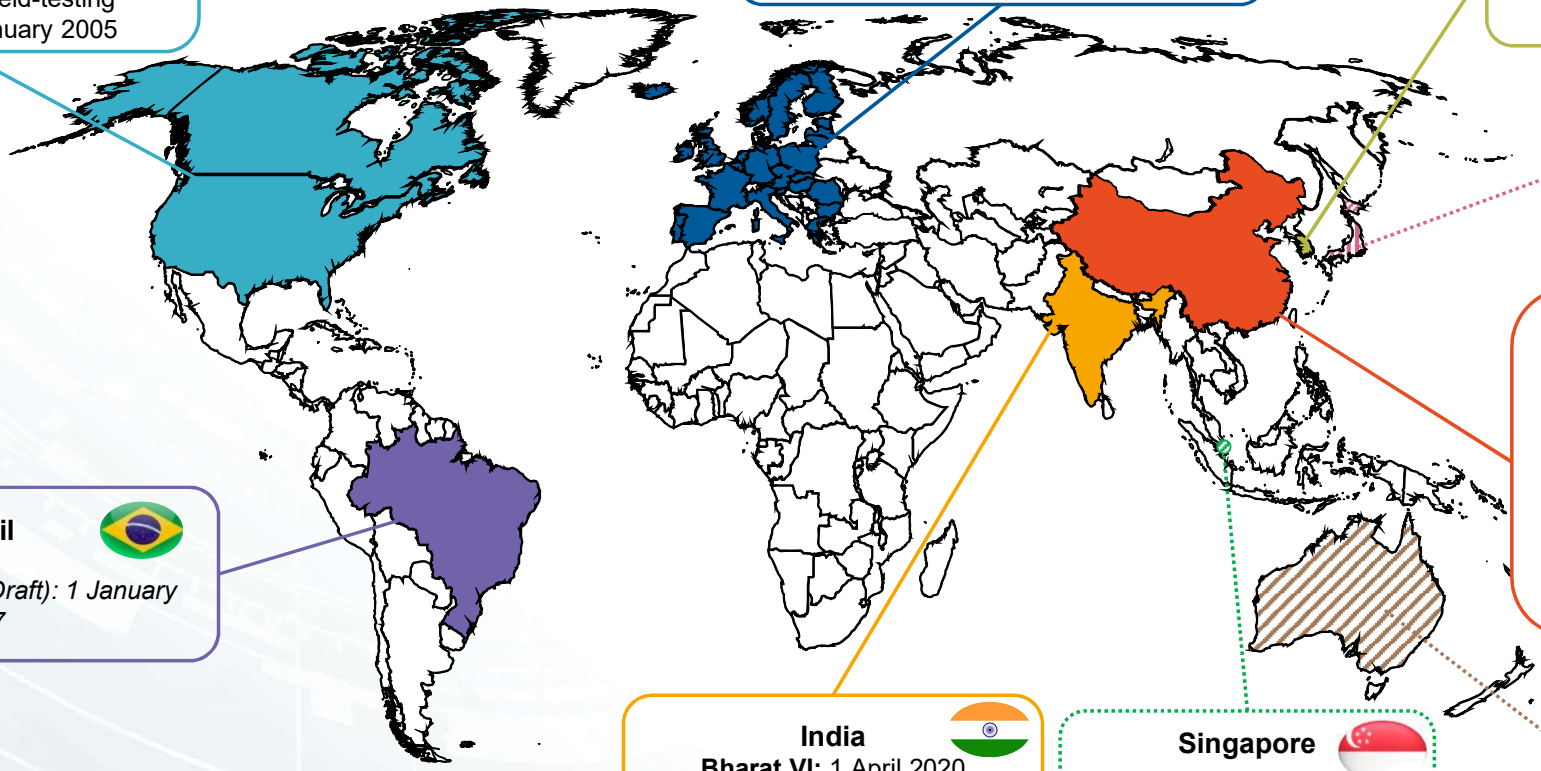
under discussion, earliest introduction 2022

China

Phase V: 1 October 2017 all newly approved vehicle type
Phase VI *(Draft):*
1 January 2020 Phase VIa (urban vehicles)
1 January 2021 Phase Via (all vehicles)
1 January 2023 Phase VIb

Brazil

PROCONVE P-8 *(Draft): 1 January 2027*



India

Bharat VI: 1 April 2020 monitoring
1 April 2023 limitation (CF)

Singapore

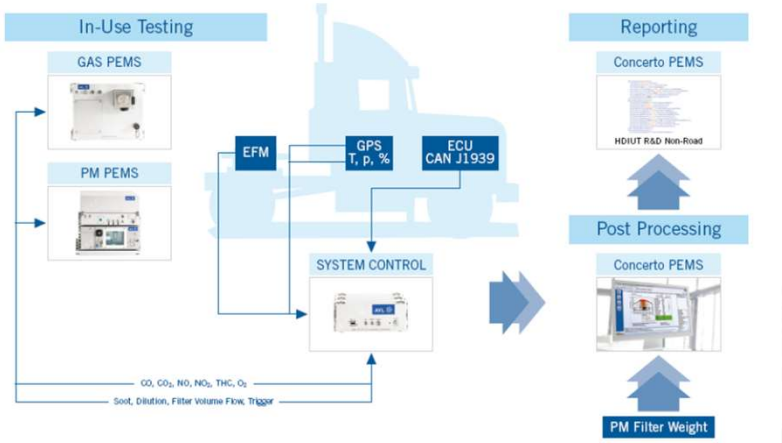
Euro VI: *1 January 2018*
PEMS only in TA

Australia

Euro VI *under discussion*

Heavy Duty – PEMS Testing

AVL M.O.V.E GAS & PM PEMS



In-Service Emissions conformity (compliance):

- "Real Life" Test on the street with PEMS (Portable Emission Measurement System). First in-service test should be conducted at the time of type approval testing
  - CO2, CO, NOx, THC, PM (PN in discussion for EU)
  - Exhaust flow rate, Speed, n, M and GPS data.

PEMS Test

- EU testing is conducted over a mix of urban (0-50 km/h), rural (50-75 km/h) and motorway (> 75 km/h) conditions, with exact percentages of these conditions depending on vehicle category.

Ambient conditions

- Temperature and Altitude as defines for off cycle emission requirements

Limits and Result calculation

- Limits are based on the laboratory limits multiplied by 1.5
- EU Result calculation by "Work based window"
- US Result calculation by NTE-Events (during ≥30seconds operation with high enough engine torque, speed and power

HDV – In Service Compliance Testing
PN Introduction

European Commission

PEMS PN procedure with conformity factors

- *The assessment of JRC in 2015 has proved a technical feasibility of the PEMS equipment to measure particulate number*
- *PEMS PN procedure will be introduced together with the 10% power threshold requirement – 1.09.2018 for new types, one year later for all new vehicles*
- *On-going tests on different vehicles*
- *Proposal to be prepared still in 2017*

2015:
PM will be replaced by PN

PM PEMS	PN PEMS
	

2017:
PN for HDV will be introduced delayed by 2019

AVL CONCERTO 5™ - M.O.V.E DATA TOOLBOX
EURO VI – In-Service Conformity (ISC)

Table 6a (COMMISSION REGULATION (EU) No 64/2012)						
Truck						
Vehicle type (e.g. M 3 , N 3 and application e.g. rigid or articulated truck, city bus)	XXX					
Vehicle description (e.g. vehicle model, prototype)	YYY					
	CO	THC	NMHC	CH4	NOx	PM
Pass-fail results	passed	failed			failed	passed
Work window conformity factor	0.06	1.52	n/a	n/a	6.81	0.85
CO2 mass window conformity factor	0.05	1.34	n/a	n/a	5.72	0.86
Trip Information	Urban		Rural		Motorway	
Shares of time of the trip in % characterised by urban, rural and motorway operation as described in point 4.5 of Annex II to Regulation (EU) No 582/2011	51.8		21.2		27.0	
Shares of time of the trip in % characterised by accelerating, decelerating, cruising and stop as described in point 4.5.5 of Annex II to Regulation (EU) No 582/2011						
Accelerating	16.9	%				
Decelerating	15.3	%				
Cruising	52.6	%				
Stop	15.2	%				
	Minimum		Maximum			
Work window average power (%)	15.1		35.8			
CO2 mass window duration (s)	684.0		1000.0			
Work window: percentage of valid windows	71.9					
CO2 mass window: percentage of valid window	55.6					
Fuel consumption consistency ratio	m = 0.93					
	r^2 = 0.88					

Legislative Reports

Case: Truck
Page: Work Window

'hello2'
Start Date: 04/23/2012
Start Time: 09:44:08.0

AVL Concerto M.O.V.E, 2014

reference Work	kWh	10.55	Points total	-	13128.00	Max. Span Drift	%	< 2
EU Power Threshold	%	15.00	Data Coverage No.	-	11555.00	Max. Zero Drift	%	< 2
min Power	%	15.15	Data Coverage Perc	%	88.02	Max. Diff. Drift Correction	%	6.0
max Power	%	35.77	Work Windows total	-	8823.00			
Conformity Factor GAS	-	1.50	Valid Windows No.	-	6344.00			
Conformity Factor Particles	-	2.00	Valid Windows Perc	%	71.90			

ave BS CO	g/kWh	0.22	ave BS THC	g/kWh	0.05	ave BS NOx	g/kWh	2.28
min BS CO	g/kWh	0.18	min BS THC	g/kWh	0.01	min BS NOx	g/kWh	1.83
max BS CO	g/kWh	0.28	max BS THC	g/kWh	0.24	max BS NOx	g/kWh	3.46
90%Perc BS CO	g/kWh	0.25	90%Perc BS THC	g/kWh	0.24	90%Perc BS NOx	g/kWh	3.13
EU Limit CO	g/kWh	4.00	EU Limit THC	g/kWh	0.16	EU Limit NOx	g/kWh	0.46
Conformity Factor CO	-	0.06	Conformity Factor THC	-	1.52	Conformity Factor NOx	-	6.81
Span Drift CO	%	0.05	Span Drift THC	%	0.01	Span Drift NO	%	0.75
Zero Drift CO	%	0.01	Zero Drift THC	%	0.00	Zero Drift NO	%	0.01
						Span Drift NO2	%	0.00
						Zero Drift NO2	%	0.07

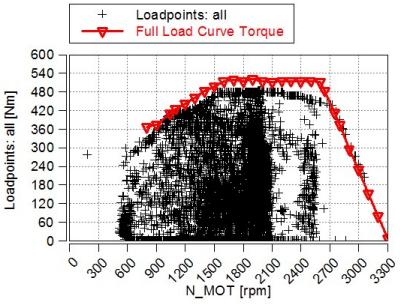
ave BS PM	g/kWh	0.00	ave BS CH4	g/kWh	0.00	ave BS NMHC	g/kWh	0.05
min BS PM	g/kWh	0.00	min BS CH4	g/kWh	0.00	min BS NMHC	g/kWh	0.01
max BS PM	g/kWh	0.01	max BS CH4	g/kWh	0.01	max BS NMHC	g/kWh	0.24
90%Perc BS PM	g/kWh	0.01	90%Perc BS CH4	g/kWh	0.01	90%Perc BS NMHC	g/kWh	0.24
EU Limit PM	g/kWh	0.01	EU Limit CH4	g/kWh	0.00	EU Limit NMHC	g/kWh	0.00
Conformity Factor PM	-	0.85	Conformity Factor CH4	-	n/a	Conformity Factor NMHC	-	n/a

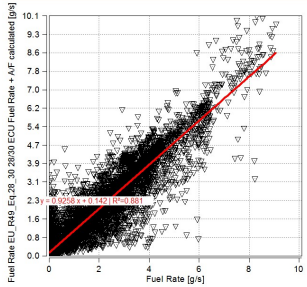
PEMS Current Case:
D:\AVL Concerto\WorkEnvironments\PEMS_Rel4_B124_BETA\PEMS\Truck.pms_c
PEMS Result Filename:
D:\AVL Concerto\MyData\TransportFiles\Truck.ctf

Vehicle: XXX / YYY
Engine: Demo Engine / Type
NOx Ambient Condition Corr.: 8 - NONE
Dry / Wet Corr.: 1 - ISO16183 [Default]

Version: Rel4_B124_BETA

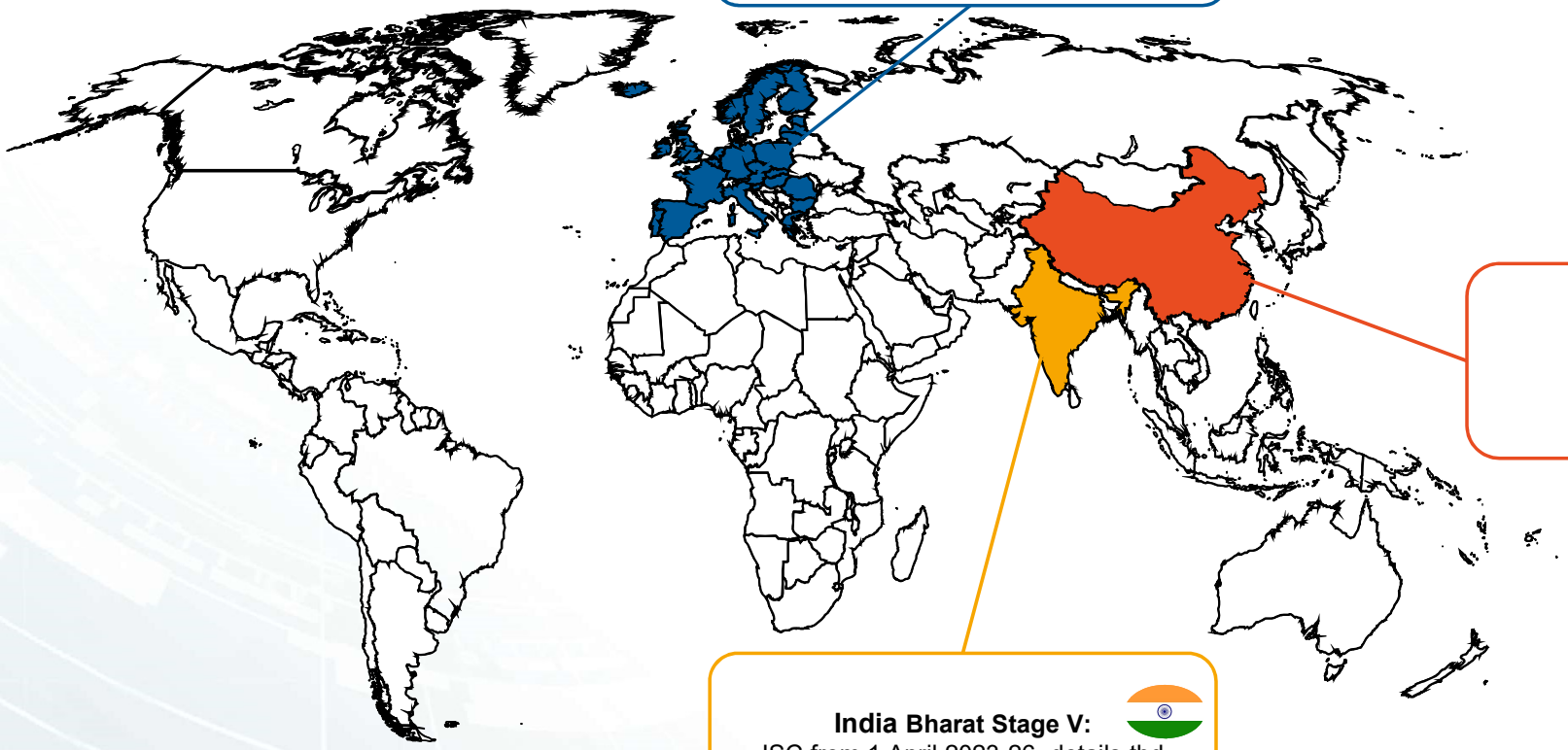
Consistency Checks





NON-ROAD MOBILE MACHINERY (NRMM) IN-USE TESTING

Non-road in-service monitoring/conformity with PEMS



EU

Stage V: 1 January 2018/2019,
submission of first results: end of 2022

China

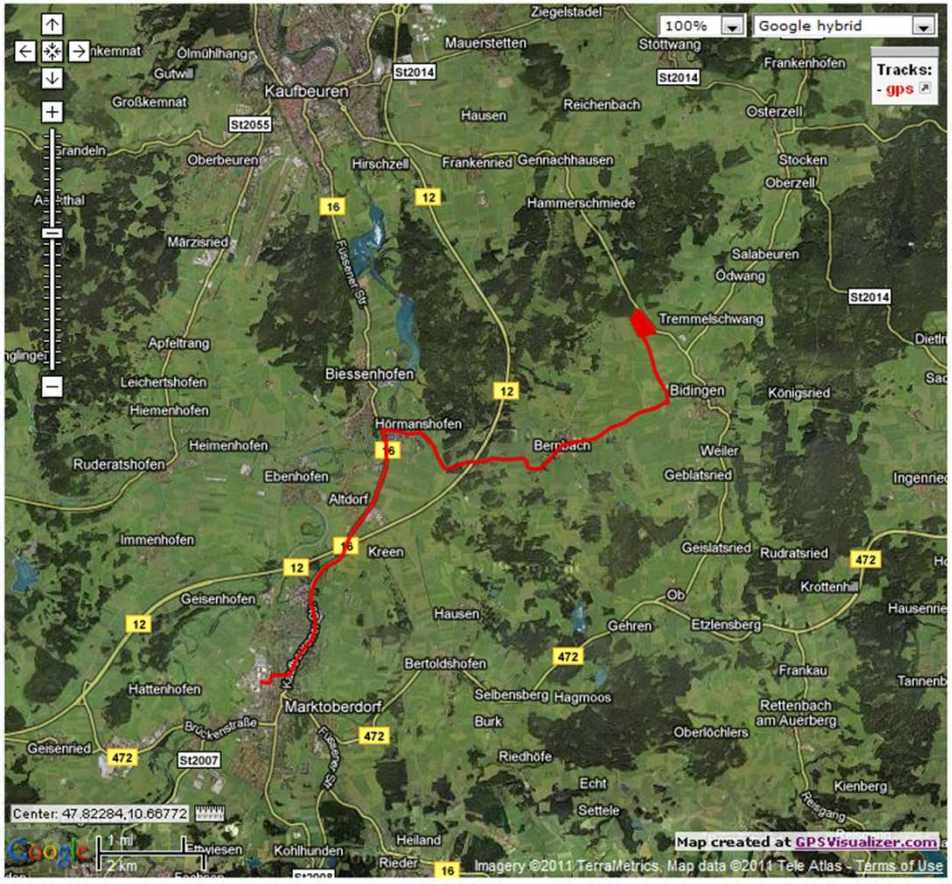
Draft China IV:
ISC from 2020
CF NO_x = 2.5

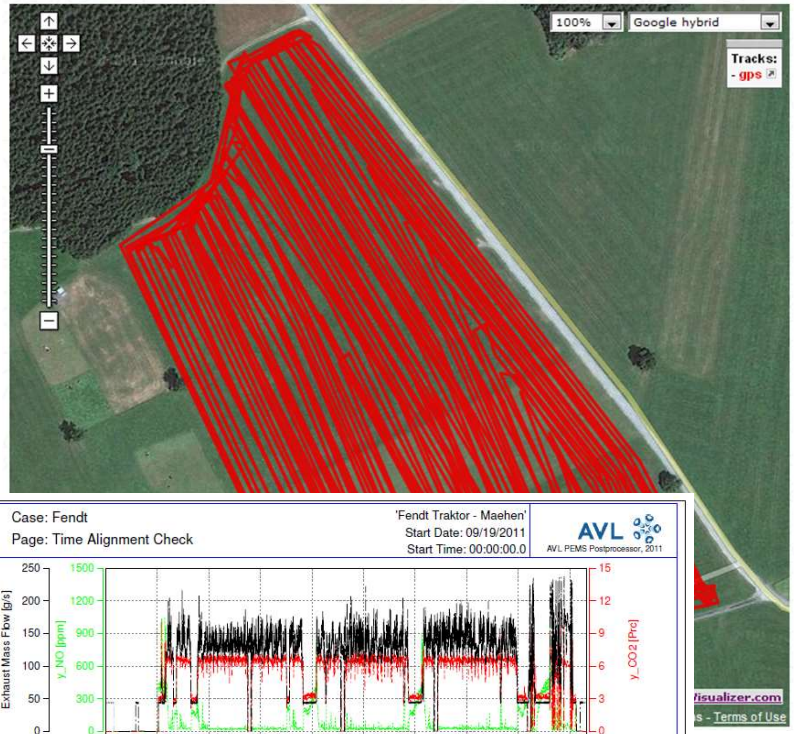
India Bharat Stage V:
ISC from 1 April 2023-26, details tbd

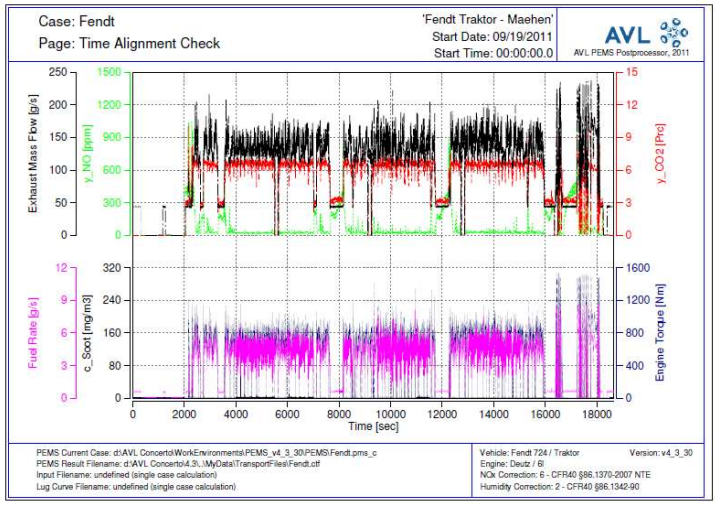
AVL M.O.V.E NRMM REFERNCE
OFF-ROAD TESTING - TRACTOR FENDT

HDIUT EXAMPLES – OFF ROAD

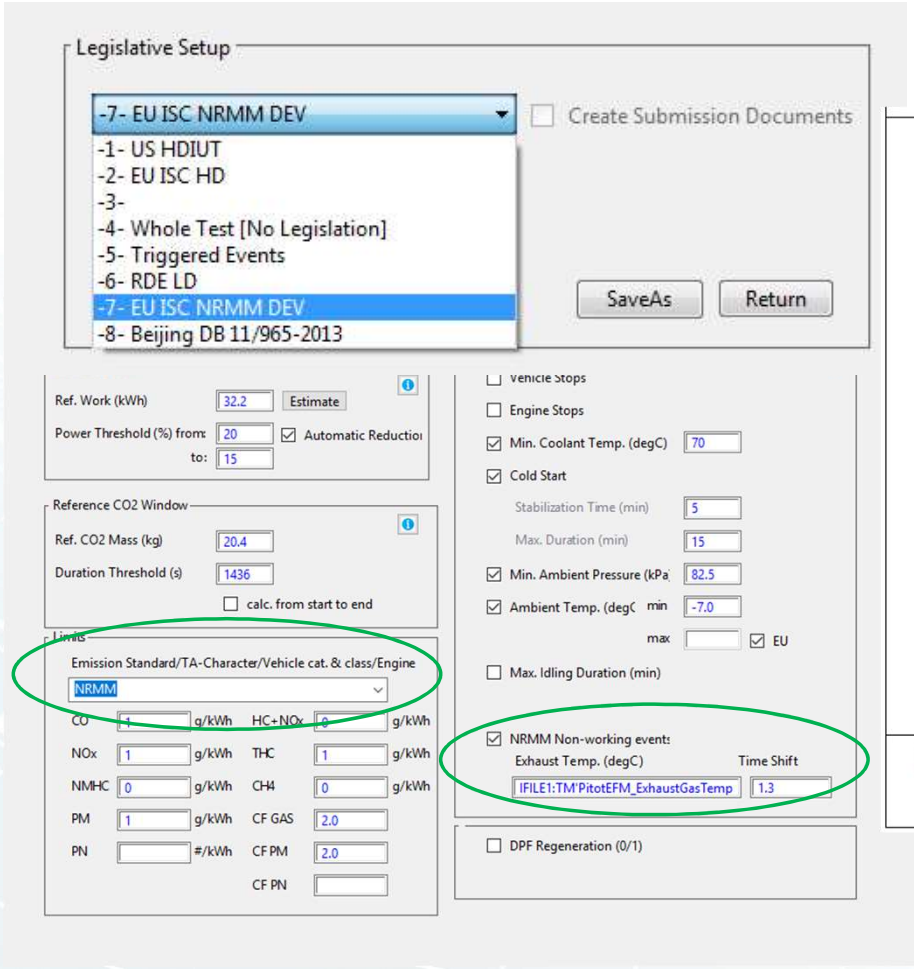
HDIUT EXAMPLES – OFF ROAD – RESULT DATA







NRMM – IN SERVICE CONFORMITY (ISC) FIRST DRAFT IMPLEMENTED



reference Work	kWh	32.20	Points total	-	13128.00	Max. Span Drift	%	< 2
EU Power Threshold	%	20.00	Data Coverage No.	-	11539.00	Max. Zero Drift	%	< 2
min Power	%	20.03	Data Coverage Perc	%	87.90	Max. Diff. Drift Correction	%	6.0
max Power	%	30.87	Work Windows total	-	5319.00			
Conformity Factor GAS	-	2.00	Valid Windows No.	-	4163.00	Min. CF NOx urban	-	2.67
Conformity Factor Particles	-	2.00	Valid Windows Perc	%	78.27			

ave BS CO	g/kWh	0.22	ave BS THC	g/kWh	0.05	ave BS NOx	g/kWh	2.26
min BS CO	g/kWh	0.20	min BS THC	g/kWh	0.01	min BS NOx	g/kWh	1.92
max BS CO	g/kWh	0.25	max BS THC	g/kWh	0.10	max BS NOx	g/kWh	2.73
90%Perc BS CO	g/kWh	0.23	90%Perc BS THC	g/kWh	0.09	90%Perc BS NOx	g/kWh	2.48
EU Limit CO	g/kWh	1.00	EU Limit THC	g/kWh	1.00	EU Limit NOx	g/kWh	1.00
Conformity Factor CO	-	0.23	Conformity Factor THC	-	0.09	Conformity Factor NOx	-	2.48
min Conformity Factor CO	g/kWh	0.20	min Conformity Factor THC	g/kWh	0.01	min Conformity Factor NOx	g/kWh	1.92
max Conformity Factor CO	g/kWh	0.25	max Conformity Factor TH	g/kWh	0.10	max Conformity Factor NO	g/kWh	2.73

ave BS PM	g/kWh	0.00	ave BS CH4	g/kWh	0.00	ave BS NMHC	g/kWh	0.05
min BS PM	g/kWh	0.00	min BS CH4	g/kWh	0.00	min BS NMHC	g/kWh	0.01
max BS PM	g/kWh	0.01	max BS CH4	g/kWh	0.00	max BS NMHC	g/kWh	0.10
90%Perc BS PM	g/kWh	0.01	90%Perc BS CH4	g/kWh	0.00	90%Perc BS NMHC	g/kWh	0.09
EU Limit PM	g/kWh	1.00	EU Limit CH4	g/kWh	0.00	EU Limit NMHC	g/kWh	0.00
Conformity Factor PM	-	0.01	Conformity Factor CH4	-	n/a	Conformity Factor NMHC	-	n/a
min Conformity Factor PM	g/kWh	0.00	min Conformity Factor CH4	g/kWh	n/a	min Conformity Factor NM	g/kWh	n/a
max Conformity Factor PM	g/kWh	0.01	max Conformity Factor CH	g/kWh	n/a	max Conformity Factor NM	g/kWh	n/a

Concerto Version: 480 Build 329, Serial Number: 998
M.O.V.E Post-Processing: DT_1R1_B207

Vehicle: XXX / YYY
Engine: Demo Engine / Type
NOx Ambient Condition Corr.: 8 - NONE
Dry / Wet Corr.: 1 - ISO16183 [Default]

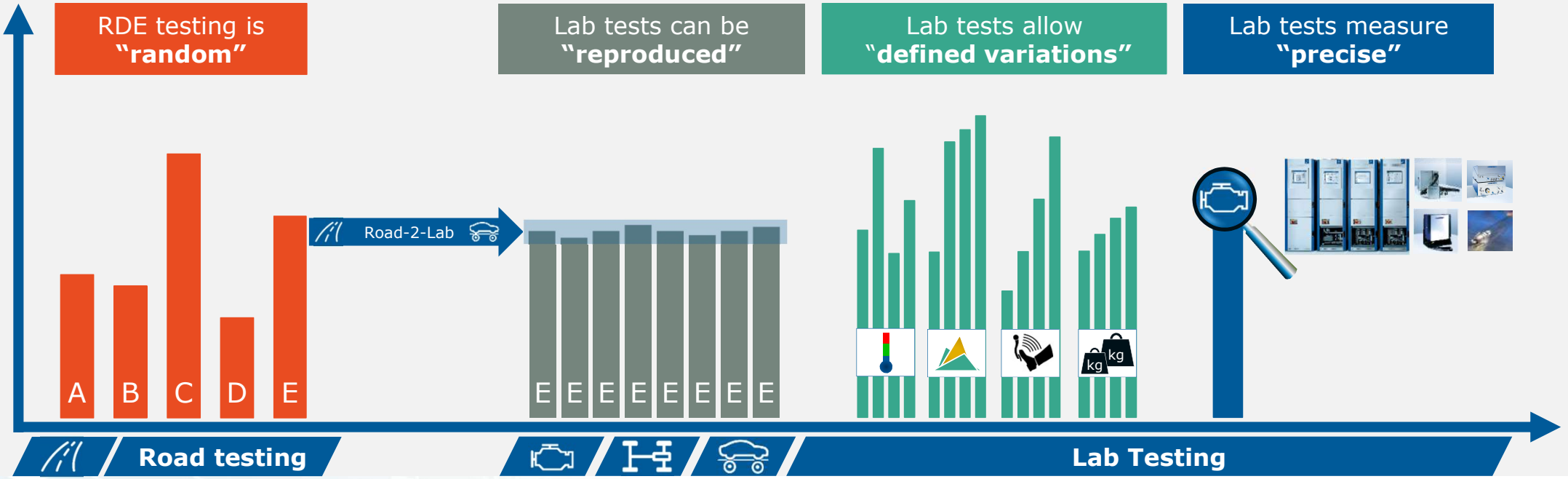
Different Applications
Different Solutions

Application	LDV	HD	NRMM
MOVE iS			 & FID iS+*	
MOVE iX				

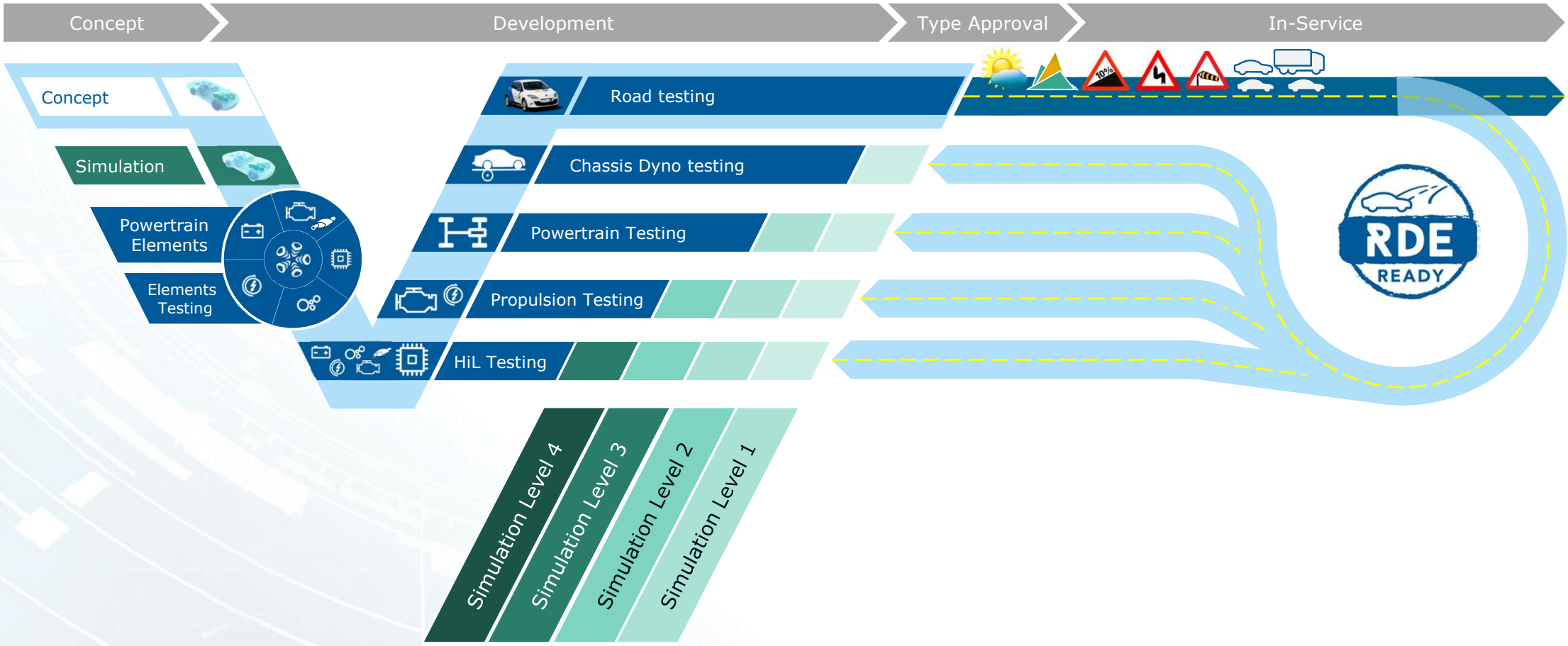
* FID iS+ from Q1/2019

RDE Development

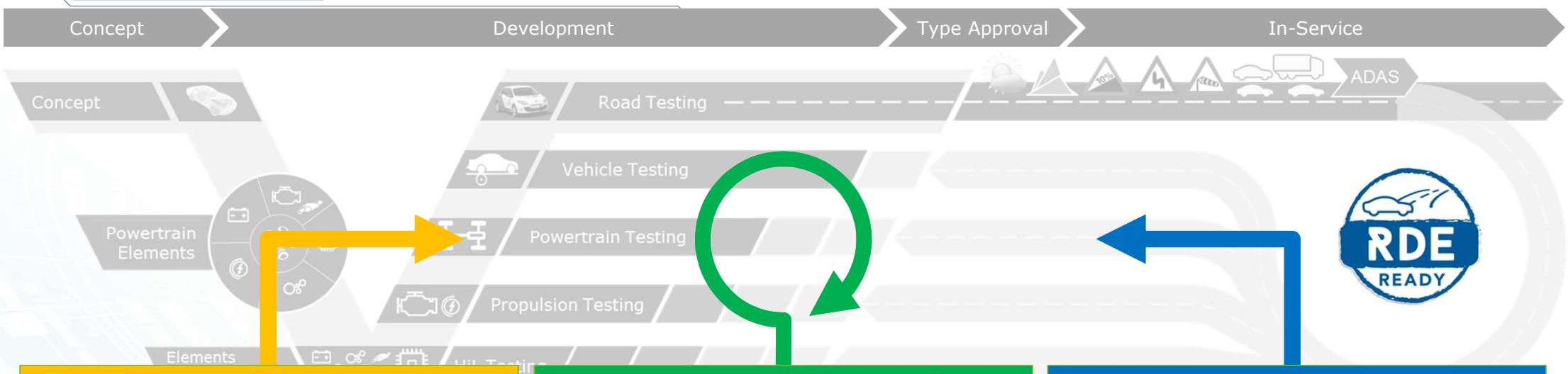
RDE Type Approval on the Road
R&D in the Lab



Powertrain Development Process



RDE Use Cases



Use Case 3: Virtual Development
- 100% Software simulation
- HiL Testing and ECU Front Loading
- Combinations of Simulation and testbeds

What	Variations of all properties
How	Traffic simulation
Why	Concepts and Front loading

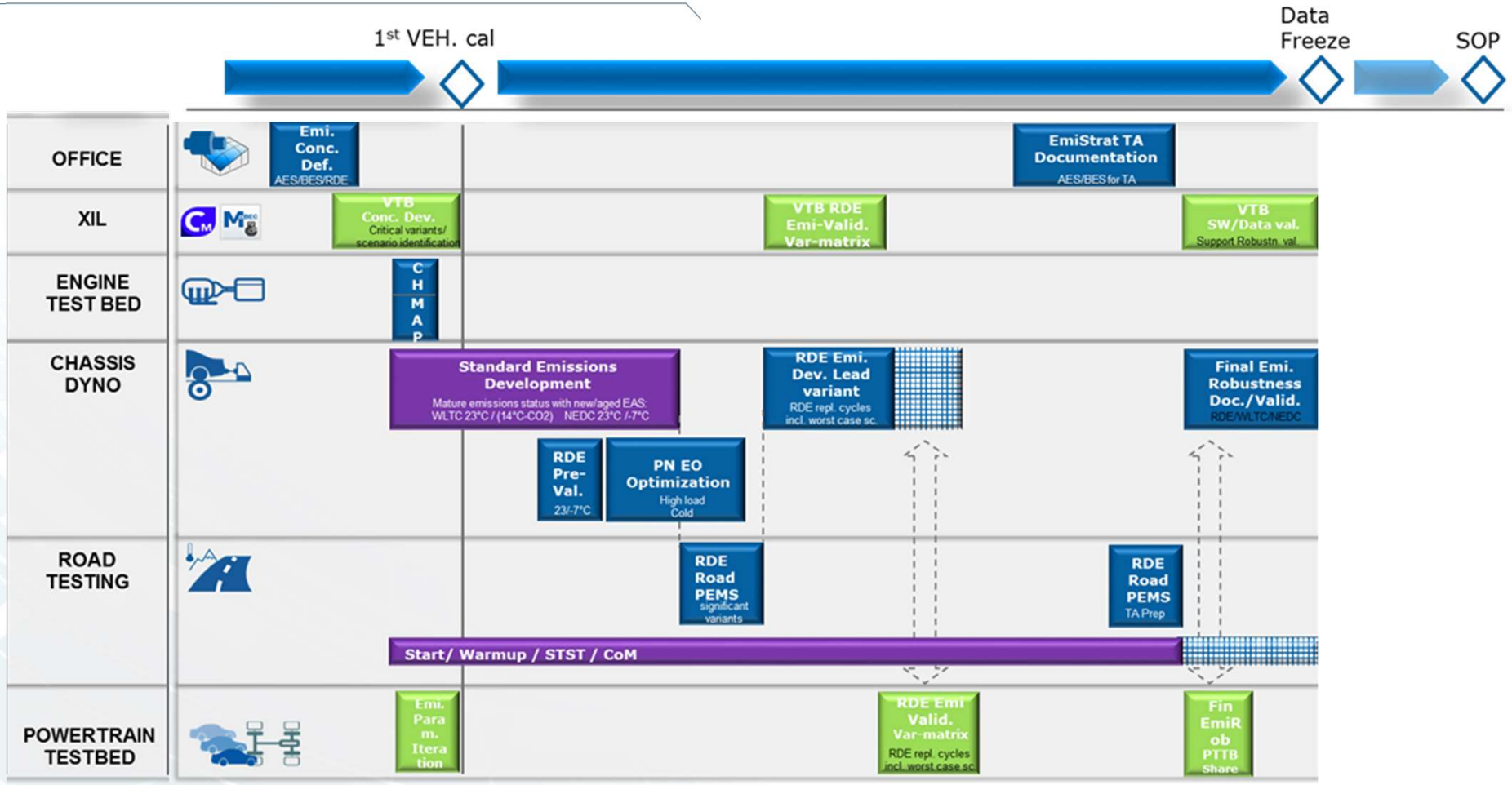
Use Case 2: "Conventional Drive Cycles"
- Standard- or OEM specific Drive Cycles
- Random Drive Cycles
- Re-Run of road testing

What	Variation of vehicle and some boundary conditions
How	Vehicle speed over time
Why	Conventional Development

Use Case 1: Reproduction
- Re-production of a road test

What	one individual road test is re-produced for the identical vehicle
How	Engine "α" replay and vehicle speed
Why	Root cause analysis

Powertrain Development Process



RDE Validation
Impact for Testing Environments

RDE Road Measurement	RDE Testing on Chassis Dyno	RDE Testing and Calibration on ETB	RDE Calibration on Virtual Test Bed
			

Same Results

Same Models | **Same Tests** | **Same Tools** | **Same Data Storage** | **Same Analysis**

AVL Road-2-Lab

Efficient Testing & Development for RDE

Thank You

RDE compliance is a must

RDE legislation is implemented on global scale

RDE development focusing on boundary conditions asks for new development approach

Additional aspects will follow like Fuel Consumption & Energy Efficiency