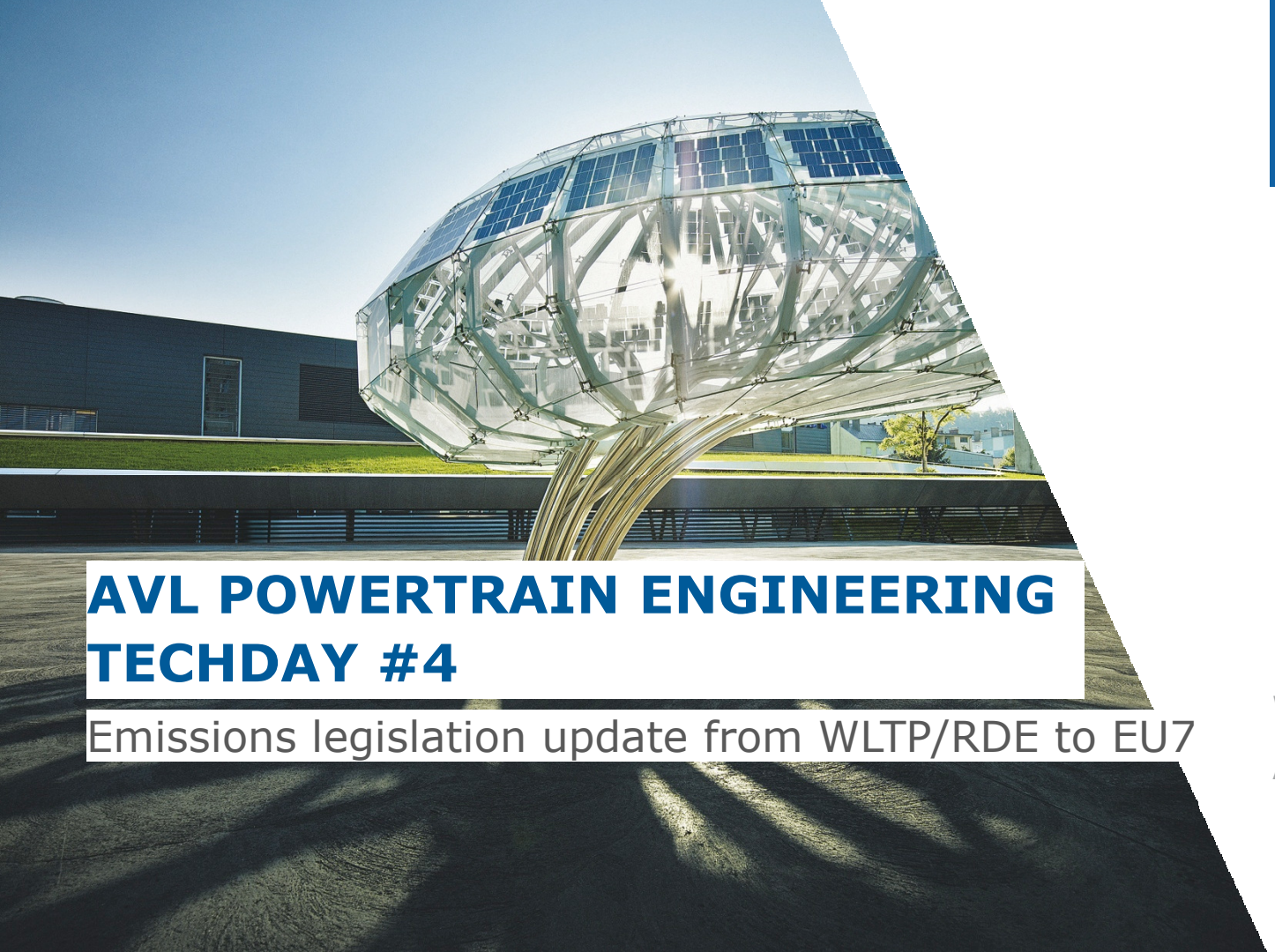

AVL POWERTRAIN ENGINEERING TECHDAY #4

Emissions legislation update from WLTP/RDE to EU7

W. Hofegger

AVL List GmbH

EMISSION REGULATION UPDATE CONTENT

- Introduction
- Update European Union RDE Status
- Update European Union WLTP
- Global Overview
- Update China
- Outlook
- AVL Legislation Services

AVL POWERTRAIN ENGINEERING TECHDAY #4
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MOTIVATION FOR NEW REGULATIONS
GAP BETWEEN TYPE APPROVAL & REAL LIFE

		2000 (Euro-3)	2005 (Euro-4)	2010 (Euro-5)	2015 (Euro-6)	2000 → 2015
NOx Real life	mg/km	1000	800	800	600	- 40%
NOx Diesel limit in lab	mg/km	500	250	180	80	- 84%
Gap between	%	100%	220%	340%	650%	

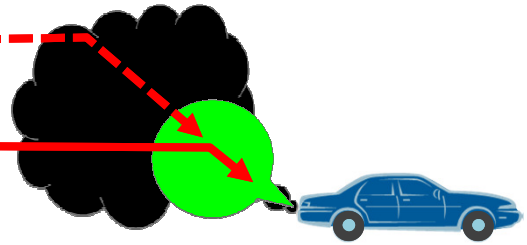
CO2 Norm emissions	g/km	172	163	140	120	- 30%
CO2 Real life	g/km	184	182	168	166	- 10%
Gap between	%	7%	12%	20%	38%	

This is only a „symbolic " presentation of the measurement data from ICCT. Nevertheless how accurate and representative this data are, it represents the motivation of the EU rule making for a new European legislation process. Data Source: ICCT International Council on Clean Transportation 2014.

REGULATION – GOAL: TO CLOSE THE GAP

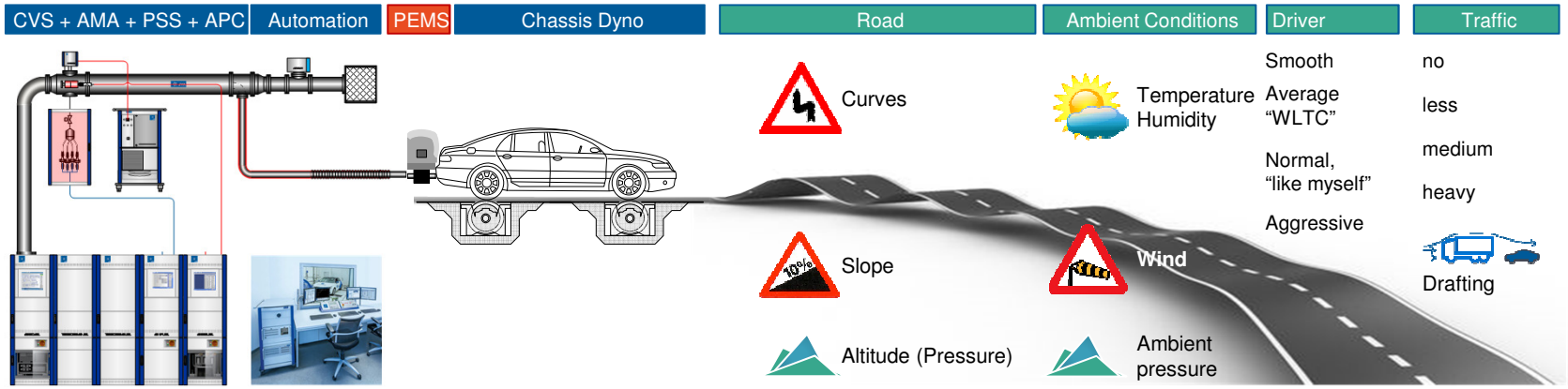
Measures:	Targets:
RDE PEMS testing	Close the gap between lab and real life pollutant emission limits
Euro-6 Limits	Further reducing NOx and PN emissions
130 → 95 gCO_2 / km	Further reducing CO_2 and fuel consumption targets
WLTP	Close the gap between norm and real life CO_2 and fuel consumption

Today pollutant emissions are in average app. 7 times (Diesel NOx) higher on the road than in the lab.

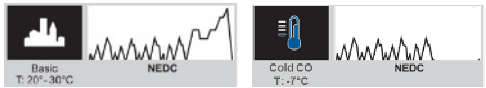


Today CO2 emissions and fuel consumption are in average app. 40% higher on the road than the declared norm values.

EMISSION TESTING TRENDS



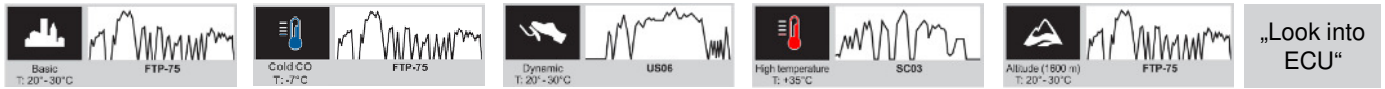
Laboratory Certification + OBD + COP + ISC



only Gasoline

Real Driving Emissions (Not to exceed limits)

Laboratory Certification + OBD + COP + ISC



„Look into ECU"

only Gasoline

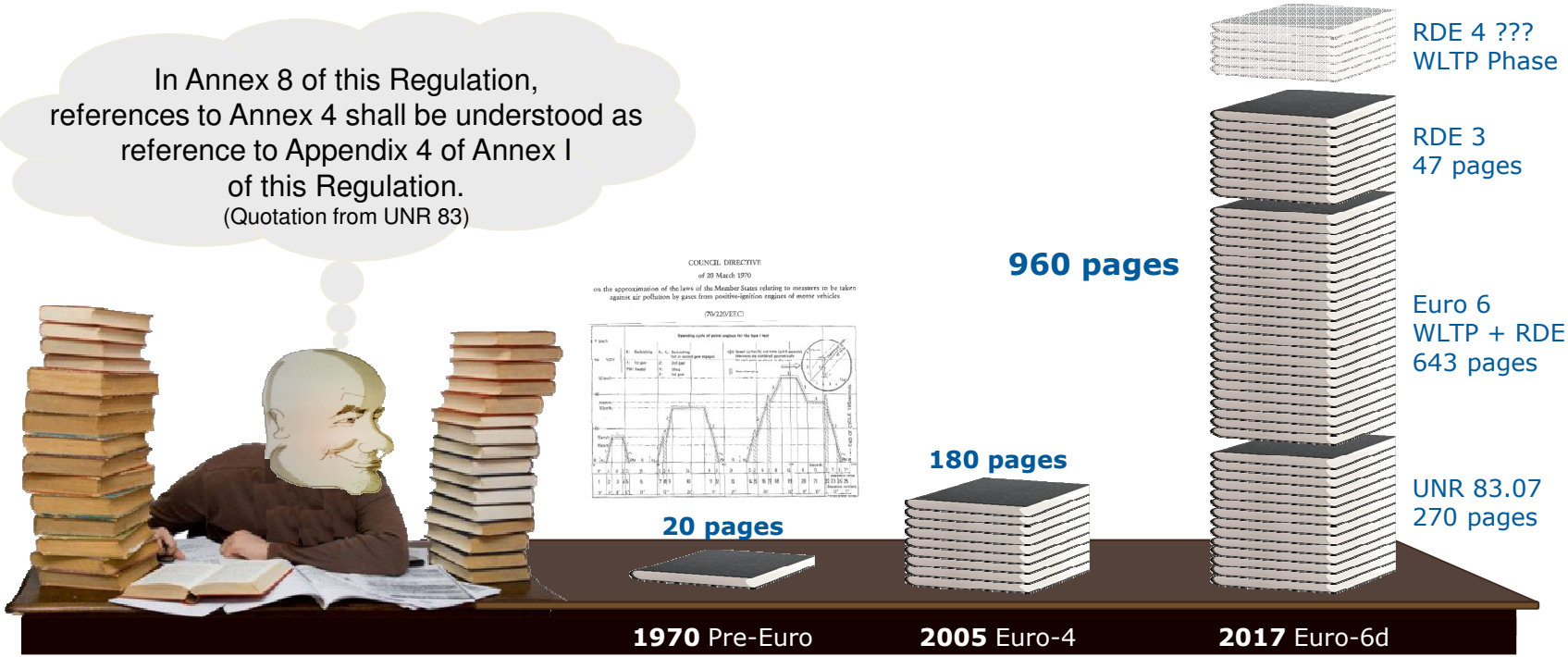
PEMS

RDE used to chase "Defeat Devices"

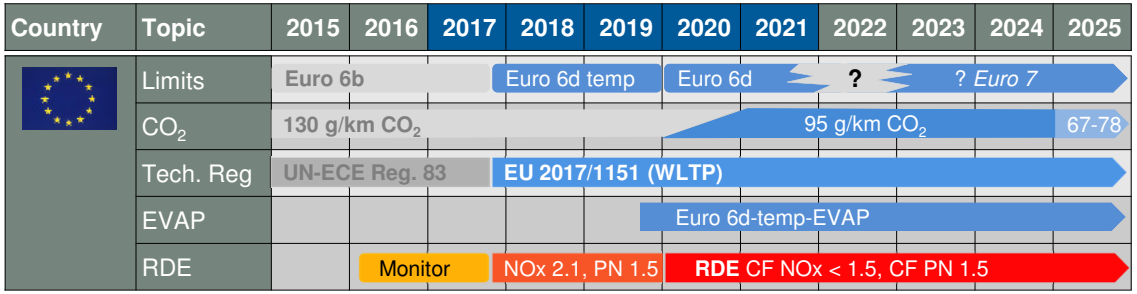
HOW REGULATION COMPLEXITY CHANGED

Example: EU Passenger Cars: Euro 0 to Euro 6d

In Annex 8 of this Regulation,
references to Annex 4 shall be understood as
reference to Appendix 4 of Annex I
of this Regulation.
(Quotation from UNR 83)



NEW CHARACTERISTIC OF LEGISLATIVE DEVELOPMENT



- 04.2016 RDE Monitoring
- 09.2017 WLTP + RDE with CF-temp.
- 09.2019 New EVAP Procedure
- 01.2020 RDE with final CF

No lead time for engineering / Last-Minute amendments

Dec. 2017 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

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RDE REGULATION STATUS

Status is based on

- Regulation (EU) 2017/1151 (implementation of WLTP in EU, incl. RDE 1st and 2nd package)
- Regulation (EU) 2017/1154 (3rd RDE package)
- Regulation (EU) 2017/1347 (Correcting Act to (EU) 2017/1151)
- EU RDE 4 working group meetings, Brussels, January to September 2017

Amendments are still possible.

Status September 2017

APPLYING OF THE RDE TEST PROCEDURE

Where should the RDE test procedure be applied?

- **Initial type approval test**: basically in parallel to the type 1 test (WLTP)
- **In-service-conformity**: basically in parallel to the type 1 test
- **Member State surveillance testing**: to be defined at a later stage since only to be applied after introduction of mandatory NTE emission limits
- **Conformity of production test**: no RDE testing is foreseen for the moment

RDE IMPLEMENTATION – 4 PACKAGES (1+2)

The Commission is planning to adopt the RDE legislation in four legislative packages:

1st package
(published March 31, 2016)

- Test procedure for gaseous pollutants
- Instrument specifications
- Trip requirements
- Non-dynamic boundary conditions
- Trip evaluation with evaluation tools EMROAD and CLEAR

2nd package
(published April 20, 2016)

- Temporary and final conformity factor NO_x
- Implementation dates for not-to-exceed limits for NO_x
- Complementary dynamic boundary conditions
  - v^*a_{pos} (acceleration x speed)
  - Relative positive acceleration
  - Positive elevation gain

Source: "Real Driving Emissions (RDE) Portable Emission Measurement Systems (PEMS) Particle Number (PN) Implementing PN-PEMS for RDE procedures", B. Giesachkiel, 3rd International Conference Real Driving Emissions, October 2015, Berlin

RDE IMPLEMENTATION – 4 PACKAGES (3+4)

The Commission is planning to adopt the RDE legislation in four legislative packages:

3rd package
(published July 7, 2017)

- Test procedure for particulate number
- CF for PN
- Instrument specifications (PN)
- Cold start
- Special provisions for hybrids
- Regeneration
- Special provisions for small and ultra-small volume manufacturers
- Special provisions for vehicles with speed limiters

4th package
(draft Q4 2017?)

- In-service compliance
- Administrative rules
- Technical rules
- Transfer functions?
- Review of:
  - Hybrid evaluation
  - Evaluation methods
  - Conformity factors

Currently under discussion

Source: "Real Driving Emissions (RDE) Portable Emission Measurement Systems (PEMS) Particle Number (PN) Implementing PN-PEMS for RDE procedures", B. Giesachkiel, 3rd International Conference Real Driving Emissions, October 2015, Berlin

SUMMARY

(EU) 2017/1151: published 07.07.2017

WLTP 2nd Act: first working draft available, implementation tbd

RDE NO_x CF = 2.1/1.5, included in WLTP 1st Act

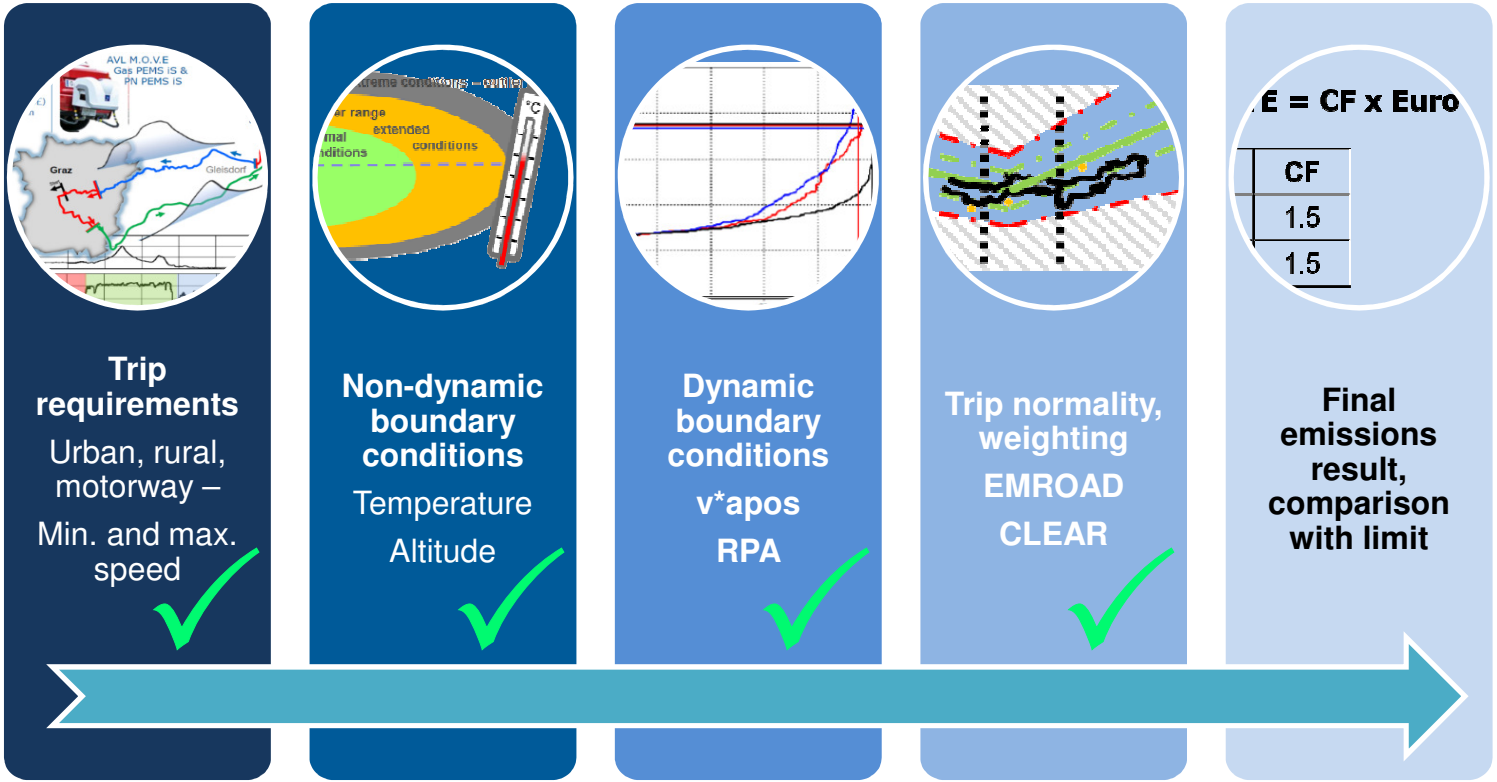
NO_x CF	New type approval	All new registrations
M1, M2, N1 class 1	1 September 2017 / 1 January 2020	1 September 2019 / 1 January 2021
N1 class II and III, N2	1 September 2018 / 1 January 2021	1 September 2020 / 1 January 2022

RDE PN CF = 1.5, Regulation (EU) 2017/1154 (RDE package 3)

PN CF	New type approval	All new registrations
M1, M2, N1 class 1	1 September 2017	1 September 2018
N1 class II and III, N2	1 September 2018	1 September 2019

CO: measurement and reporting

RDE METHODOLOGY



RDE – TRIP REQUIREMENTS

3 operational parts, min. 16 km each, start with urban operation:

- **Urban** operation: vehicle speeds **up to 60 km/h**,
- **Rural** operation: vehicle speeds **between 60 and 90 km/h**,
- **Motorway** operation: speeds **above 90 km/h**

Cold & at least one hot start test required per PEMS test family

Approximately (+/- 10%)
1/3 of distance per part,
urban part: min. 29%

Trip duration: 90-120 min

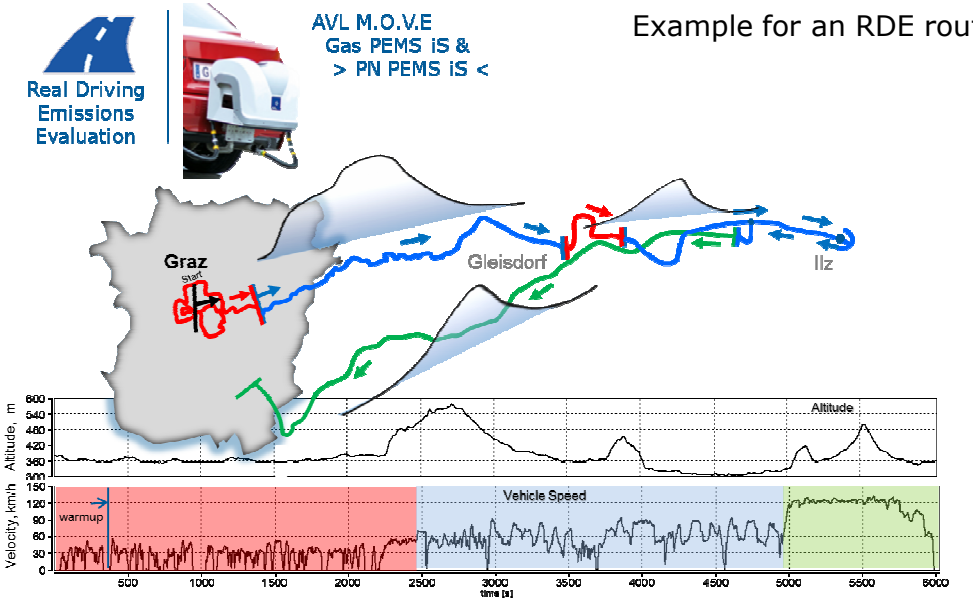
Min. 5 min > 100 km/h

At least once > 110 km/h

Max. 145 km/h (max. 160 km/h for 3% of motorway driving time)

$|\Delta$ Start-End$| \leq 100$ m

Positive cumulative altitude gain over complete trip and urban part < 1200 m/100 km

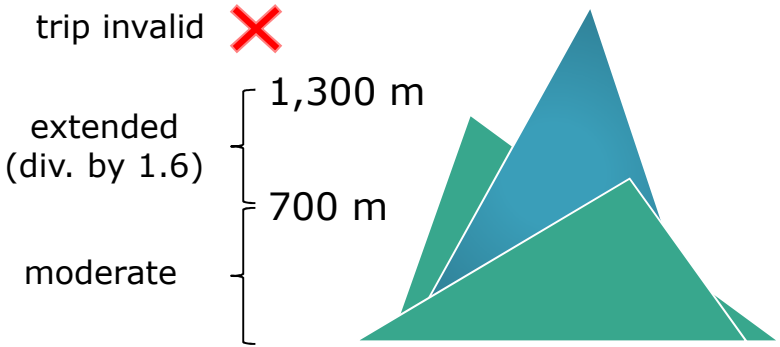


Example for an RDE route

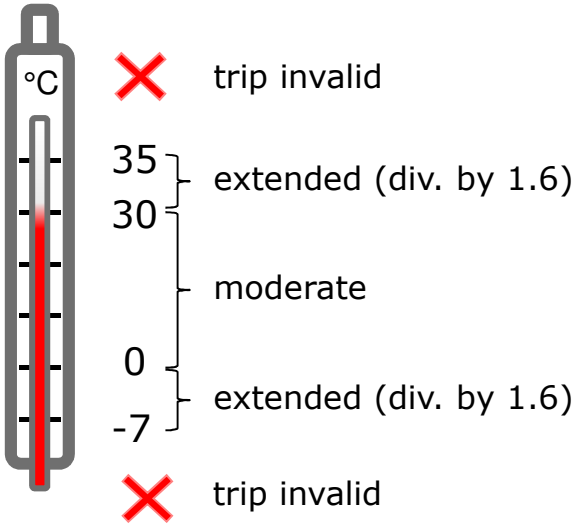
NON-DYNAMIC BOUNDARY CONDITIONS

- Non-dynamic boundary conditions: altitude, temperature
- Moderate and extended conditions
- Time interval of extended conditions: emissions divided by factor 1.6
- Part or total test outside extended conditions: trip is invalid

Altitude



Temperature



*N1 class II&III, N2: one year later

From start of binding NTE limits to 2020/2021*:
moderate: 3 – 30 °C, extended: -2 – 3, 30 – 35 °C

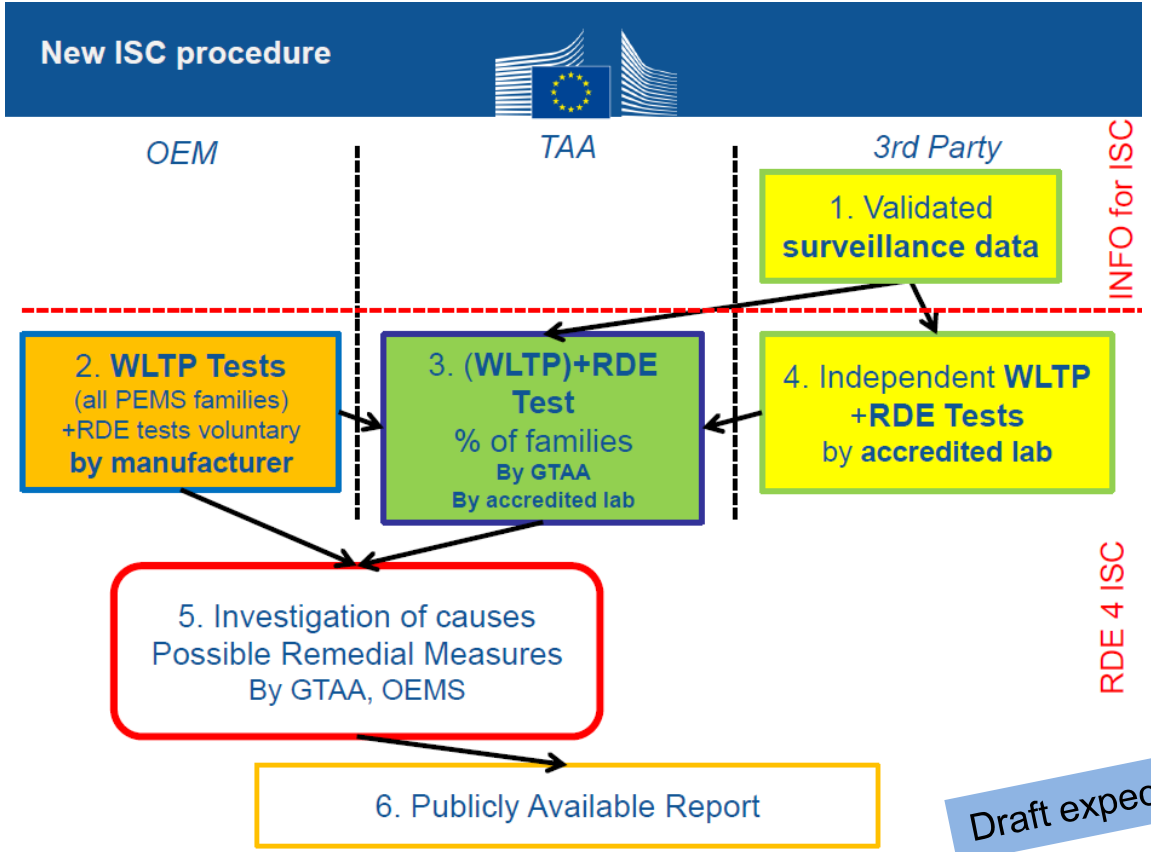
RDE PACKAGE 4
ISSUES UNDER DISCUSSION

- RDE testing during ISC, introducing the possibility for independent testing by third parties
- Dealing with issues related to LCVs, multistage and special purpose vehicles
- Transfer functions
- Gasoline fuel issue
- Guidance documents

Reviews:

- Evaluation methods (EMROAD & CLEAR)
- More representative method for testing hybrid vehicles
- Review of uncertainty margins for NO_x (CF)
- Possible review of the cold start analysis
- Review of Ki factors

RDE 4 – IN-SERVICE CONFORMITY (ISC)



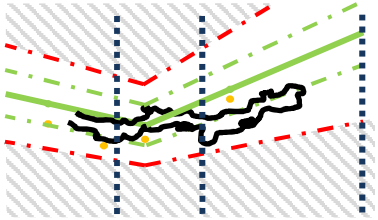
Draft expected for Q4/2017

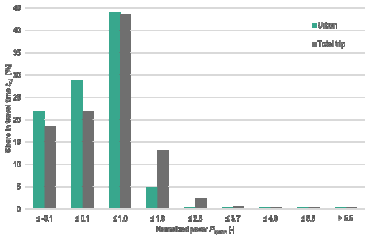
EC, 05.-06.07.2017

GTAA: granting type approval authority

RDE 4 –
REVIEW OF EVALUATION METHODS

- Currently two evaluation methods are used
  - EMROAD (Moving Average Windows)
  - CLEAR (Power Binning Method)





- Purpose of evaluation methods
  - Evaluation of trip validity
  - Trip normalization

- Goals:
  - Complete review of methods
  - Decision on one method

Draft expected for Q4/2017

RDE 4 – REVIEW OF UNCERTAINTY MARGINS

- The "final" conformity factors for NO_x and PN of 1.5 are defined as "1 + margin", with the margin for measurement uncertainties currently = 0.5 for NO_x and PN.
- The margins are subject to an **annual review** to account for the improvement of measurement equipment.
- The goal announced by the responsible European Commissioner Elzbieta Bienkowska was to reach a **CF of 1.0 by 2023**.
- The European Parliament called for a **CF of 1.0 by 2021** (see below)[1]

> 13. Urges the Commission to review in 2017 the conformity factor for RDE tests of NO_x emissions, as provided for by the 2nd RDE package; calls on the Commission to further revise the conformity factor annually, in line with technological developments, so as to bring it down to 1 by 2021 at the latest;

- Current discussions:
  - No reduction of PN margin planned during this annual review
  - Reduction of NO_x margin planned (new value to be defined)

Draft expected for Q4/2017

[1]Inquiry into emission measurements in the automotive sector: European Parliament recommendation of 4 April 2017 to the Council and the Commission following the inquiry into emission measurements in the automotive sector

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STATUS NEW EU WLTP REGULATION

The WLTP test procedure is transposed into European legislation by a new Implementing Regulation (EU) 2017/1151 (WLTP 1st Act).

The new Regulation (EU) 2017/1151 (WLTP 1st Act) will be mandatory from:

	New type approval	All new registrations
M1, M2, N1 class I	1 September 2017	1 September 2018
N1 class II and III, N2	1 September 2018	1 September 2019

Currently under discussion: WLTP 2nd Act

- Correction of test flexibilities (test speed and distance, driving trace violations)
- Transparency of test parameters to enable third party testing
- Implementation of recent changes to gtr15 (WLTP on UN ECE level)
- Implementation of new EVAP gtr into EU Regulation
- On-board fuel consumption monitoring
- Draft expected for Q4 2017

NEW EU LIGHT PASSENGER AND COMMERCIAL VEHICLES REGULATION STRUCTURE

Regulation (EC) No 715/2007

Common technical requirements for type approval

Regulation (EC) No 692/2008

Implementation measures;
Alignment with ECE Regulations:
Basis ECE Regulations + additional requirements

Will be repealed

Commission Regulation (EU) 2017/1151 (WLTP 1st Act)

supplementing Regulation (EC) No 715/2007 and amending Directive 2007/46/EC of the European Parliament and of the Council, Commission Regulation (EC) No 692/2008 and Commission Regulation (EU) No 1230/2012 and repealing Regulation (EC) No 692/2008 – **WLTP 1st Act (including RDE 1 and 2)**

Commission Regulation **(EU) 2017/1154** amending Commission Regulation **(EU) 2017/1151 – RDE 3rd package**

Commission Regulation **(EU) 2017/1347** correcting Commission Regulation **(EU) 2017/1151 – WLTP Correcting Act**

Currently under discussion – **RDE 4th package**

Currently under discussion – **WLTP 2nd Act**

UNECE
United Nations Economic Commission for Europe

New ECE Rxxx under consideration

gtr 15 WLTP

ECE R83
Exhaust Emissions

ECE R85
Net power and maximum 30 min power of electric drive trains

ECE R24
Smoke Opacity

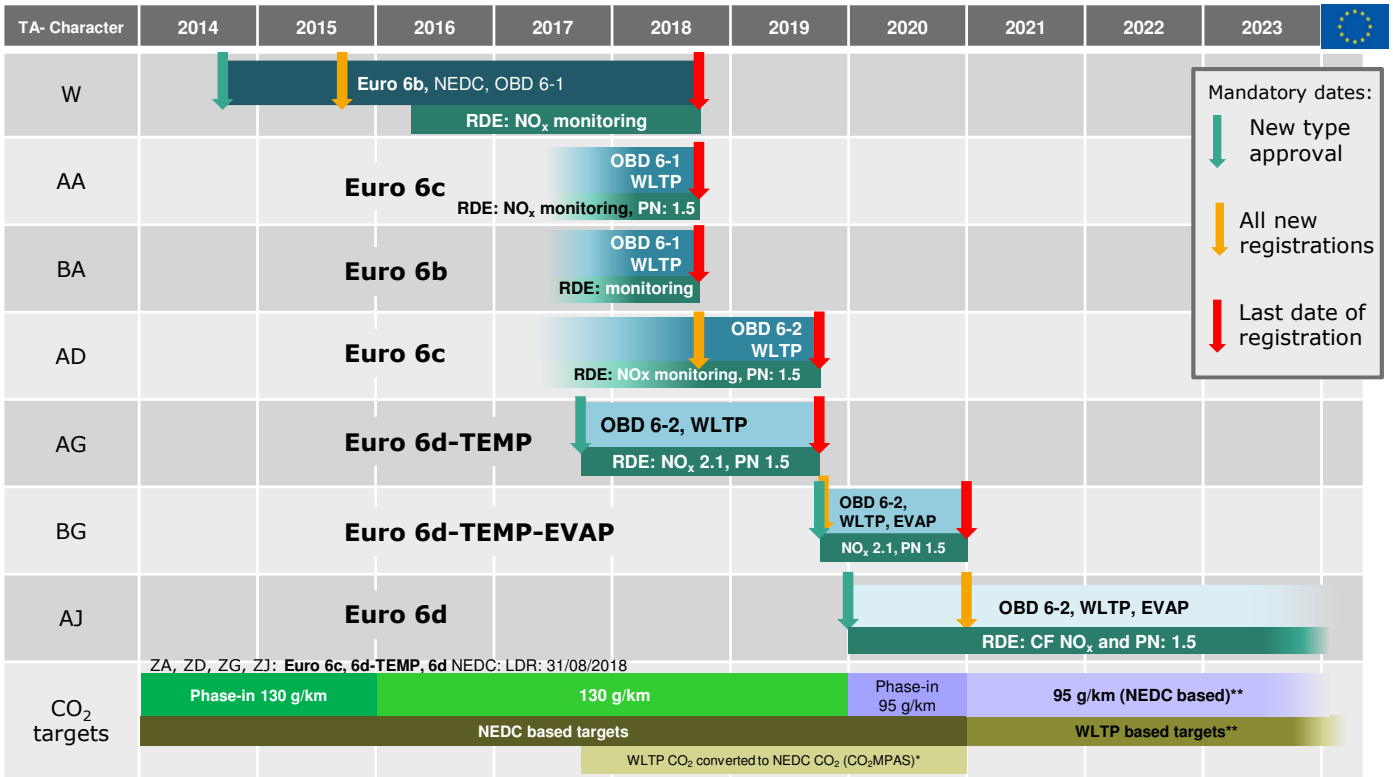
ECE R103
Replacement Pollution Control Devices as separate Technical Unit

WLTP IN EU – CURRENT STATUS

Type	Description	Dyno	Auto-mation	CVS	Emission Bench	PTS	PN	Instrum-ents	SHED	Climatic Chamber
I	Average exhaust emission after a cold start									
II	CO concentration at idling speed									
III	Emissions of crankcase gases									
IV	Evaporation emissions (SHED - Test)									
V	Durability of anti-pollution devices									
VI	Low ambient temperature (-7°C) exhaust emission									
OBD	Test of On Board Diagnostic Functionality									
	CO2 and Fuel consumption									
R24	Smoke opacity									

WLTP 1st Act	WLTP 2nd Act	WLTP future developments
01.09.2017 WLTP		All tests based on new WLTP procedure
UN-ECE R-83/ transitional provisions for EU	01.09.2019	
01.09.2017 WLTP		
→ UN-ECE R-24		

EURO 6b, 6c & 6d IMPLEMENTATION – PASSENGER CARS



*Double testing under certain conditions
** WLTP based targets will be defined based on 2020 NEDC CO_2 values.
WLTP based targets will have comparable stringency to NEDC based 95 g/km.

DQ, 24.07.2017

Status according to Regulation (EU) 2017/1151, (EU) 2017/1154, and (EU) 2017/1347, updates will be made depending on rulemaking progress

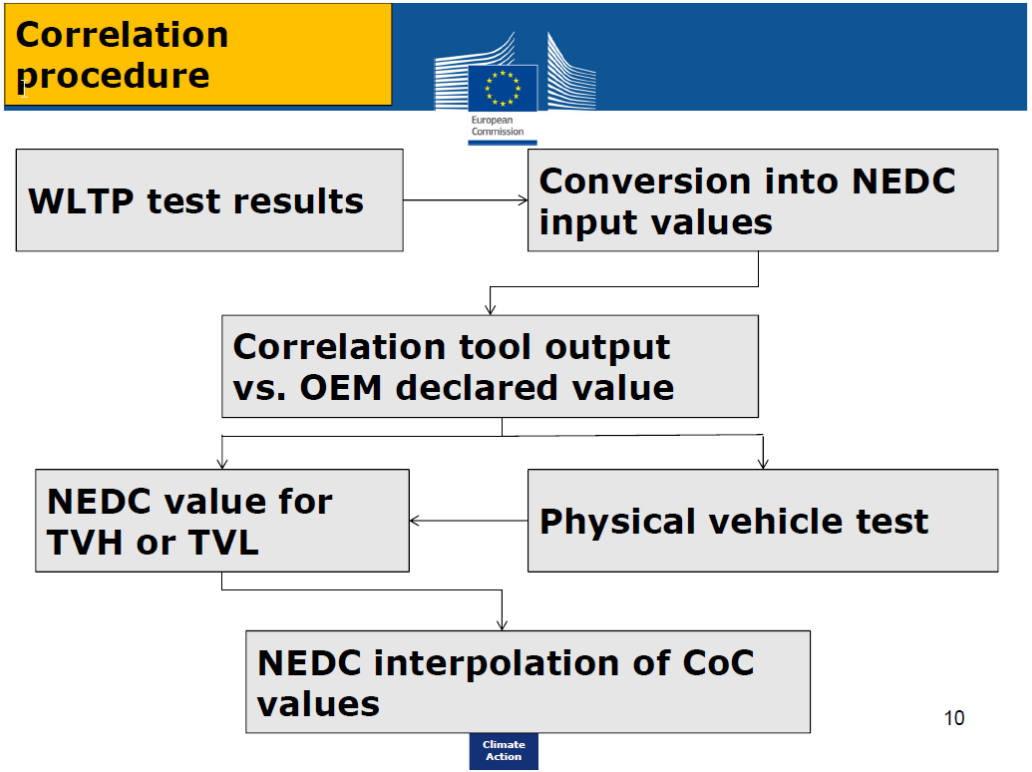
EU CO_2 EMISSIONS – TRANSITION FROM NEDC TO WLTP

Until 2020:

conversion of WLTP test results to NEDC values → CO_2MPAS simulation tool or double testing under certain conditions

From 2021:

WLTP based targets



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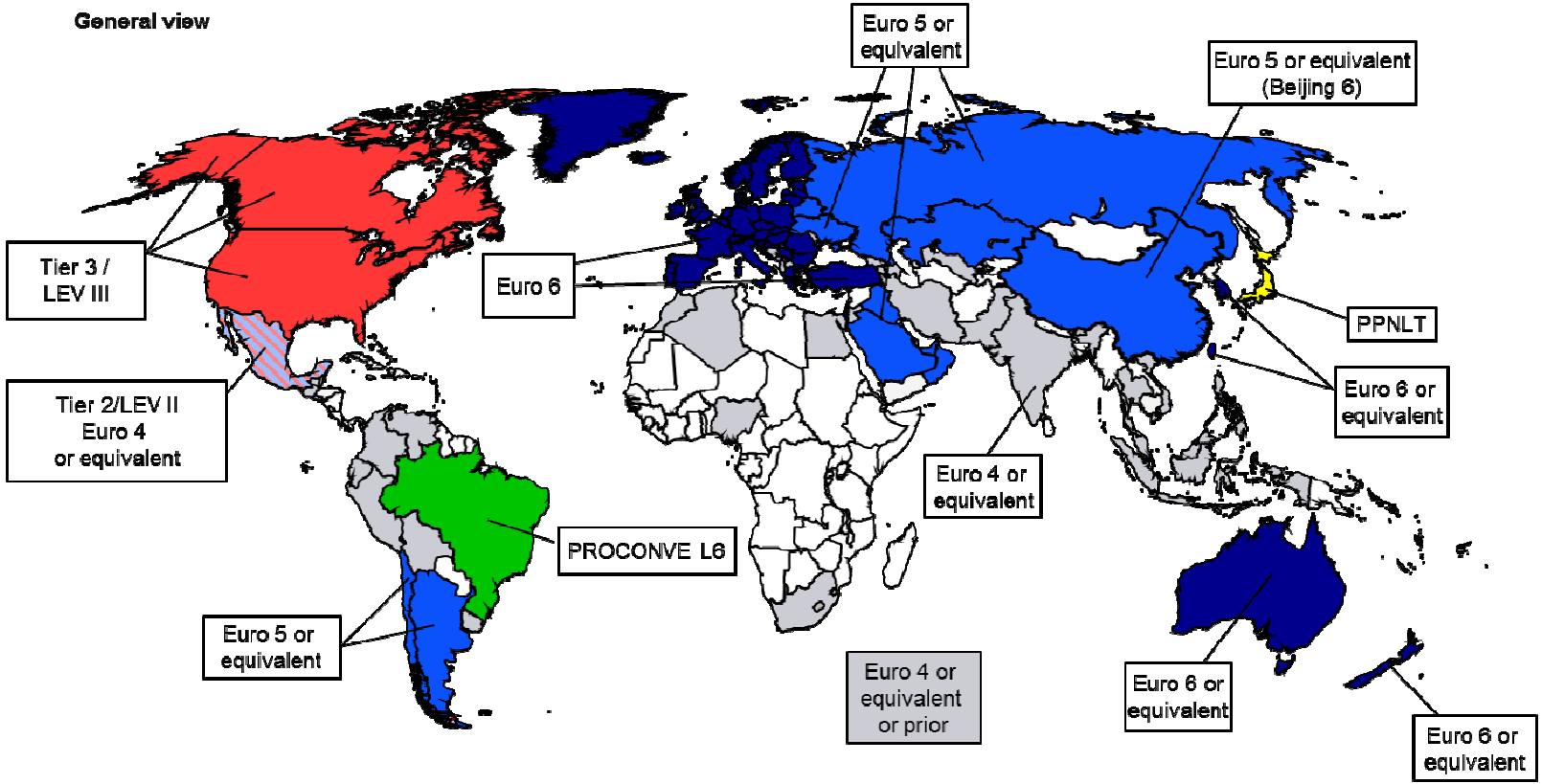
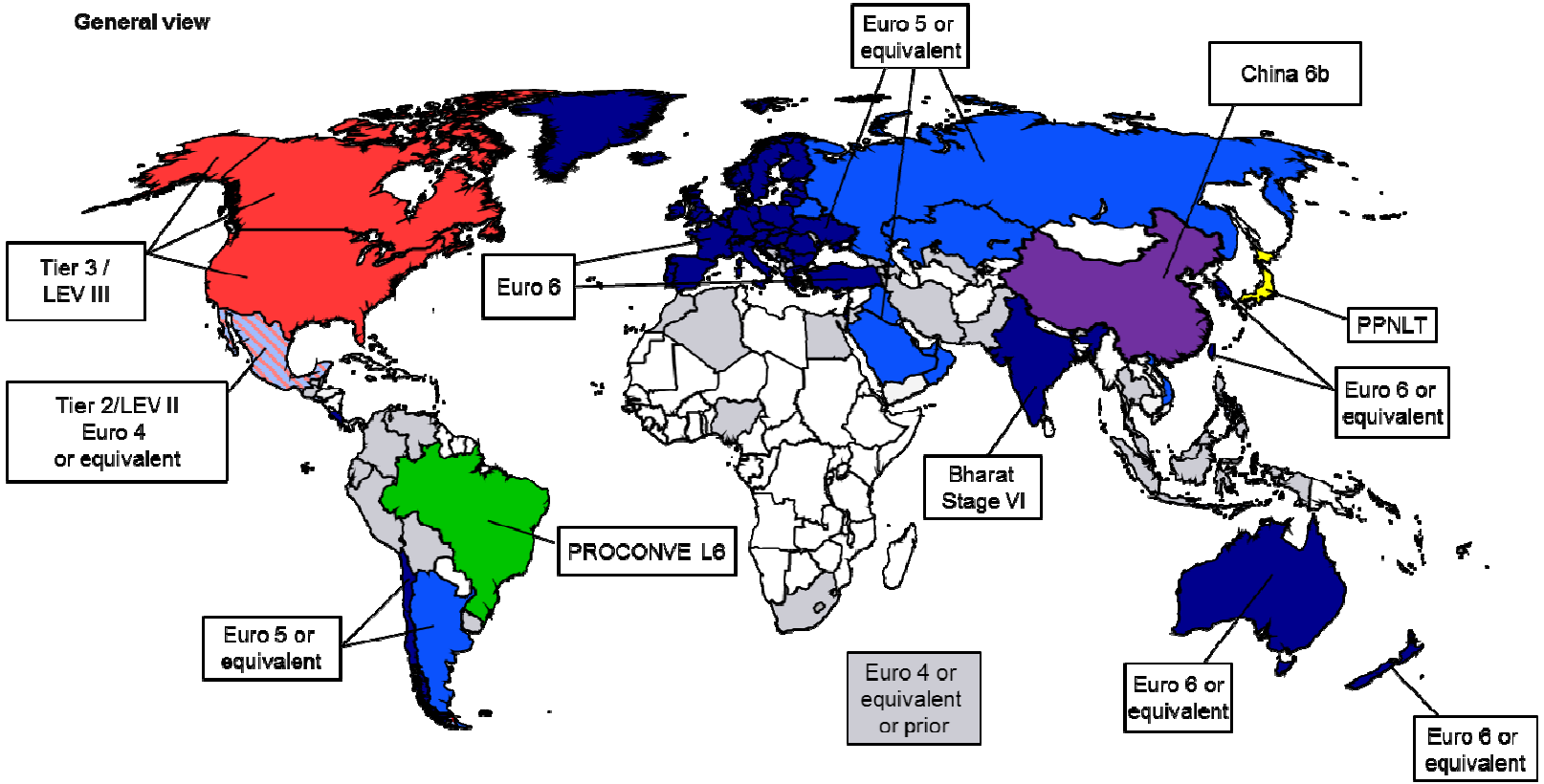
PASSENGER CAR EMISSION STANDARDS – 2018

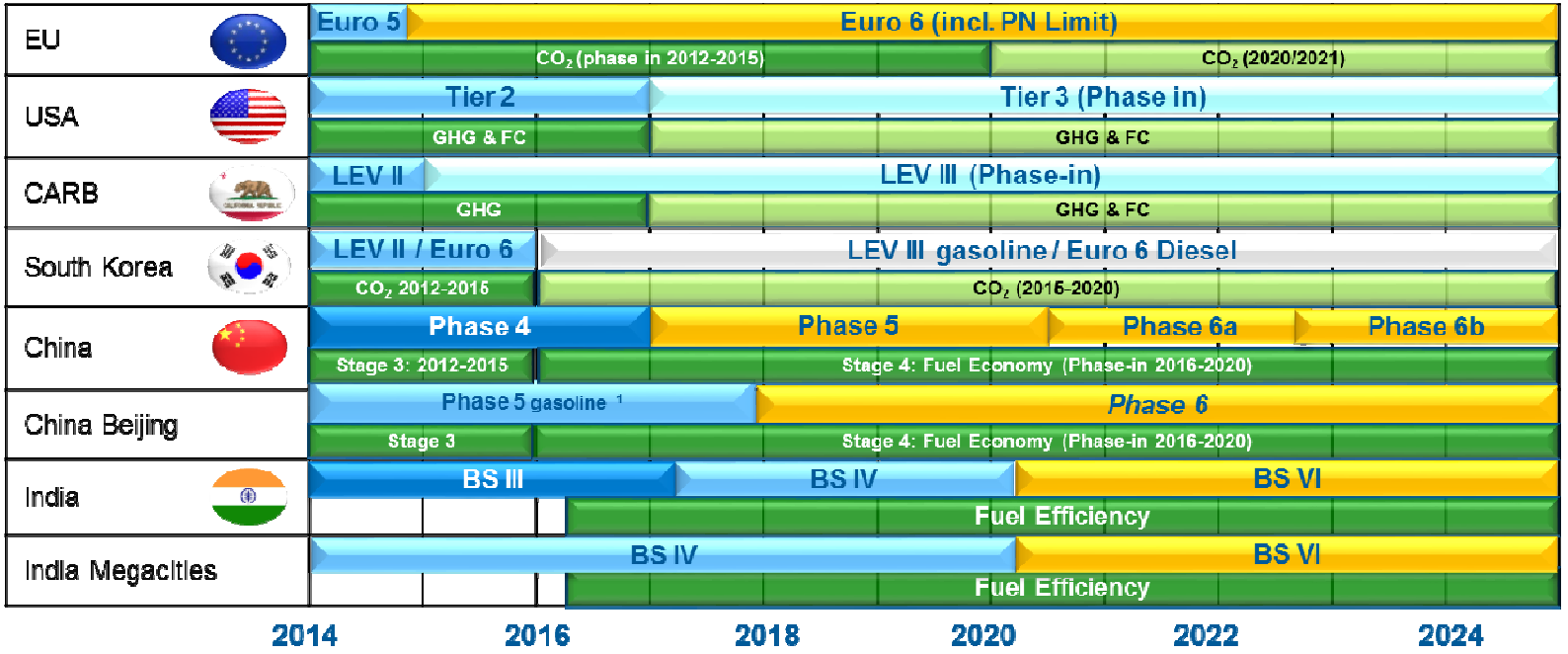


PASSENGER CAR EMISSION STANDARDS – EXPECTED 2023



WORLD-WIDE EMISSION LEGISLATION FOR PASSENGER CARS

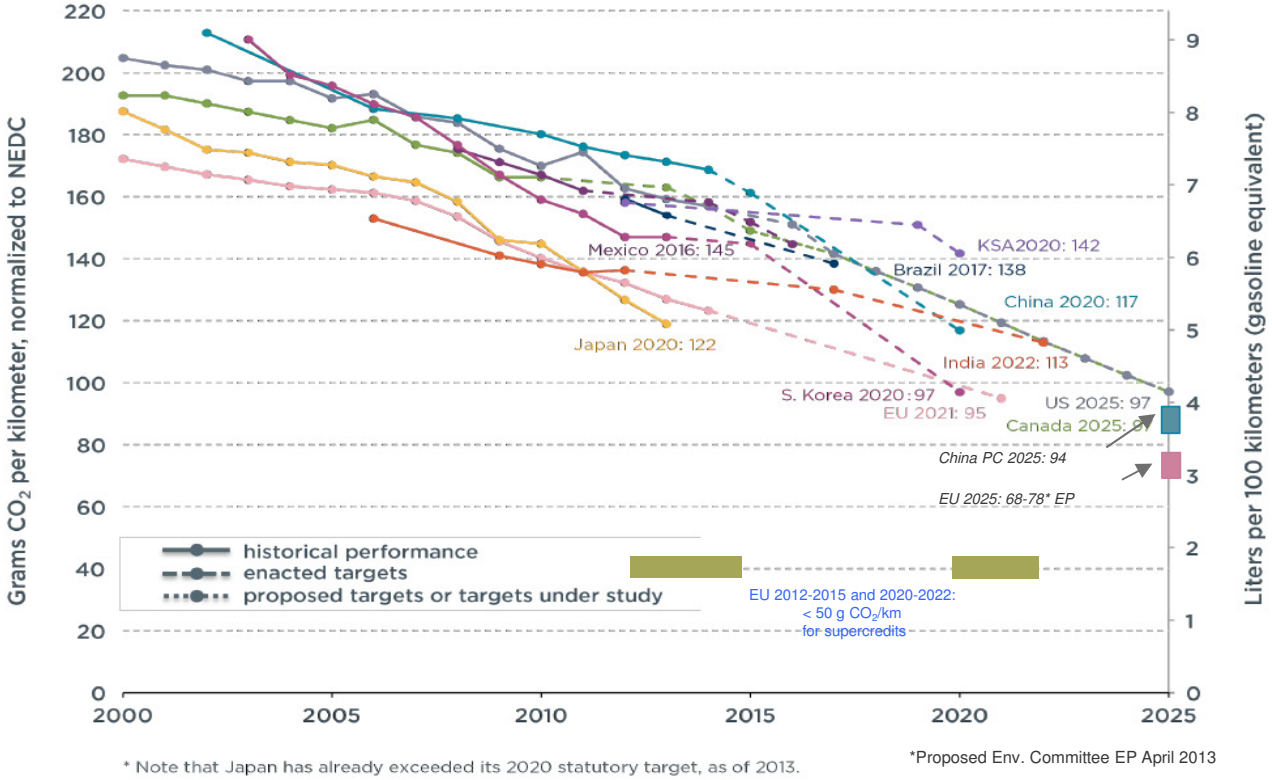
? discussion, no proposal available[1] ; *Italic proposed/announced* new type approval if applicable



[1]Phase 5 for gasoline only, Diesel banned

Recent changes

CO_2/FUEL CONSUMPTION TARGETS FOR PASSENGER CARS

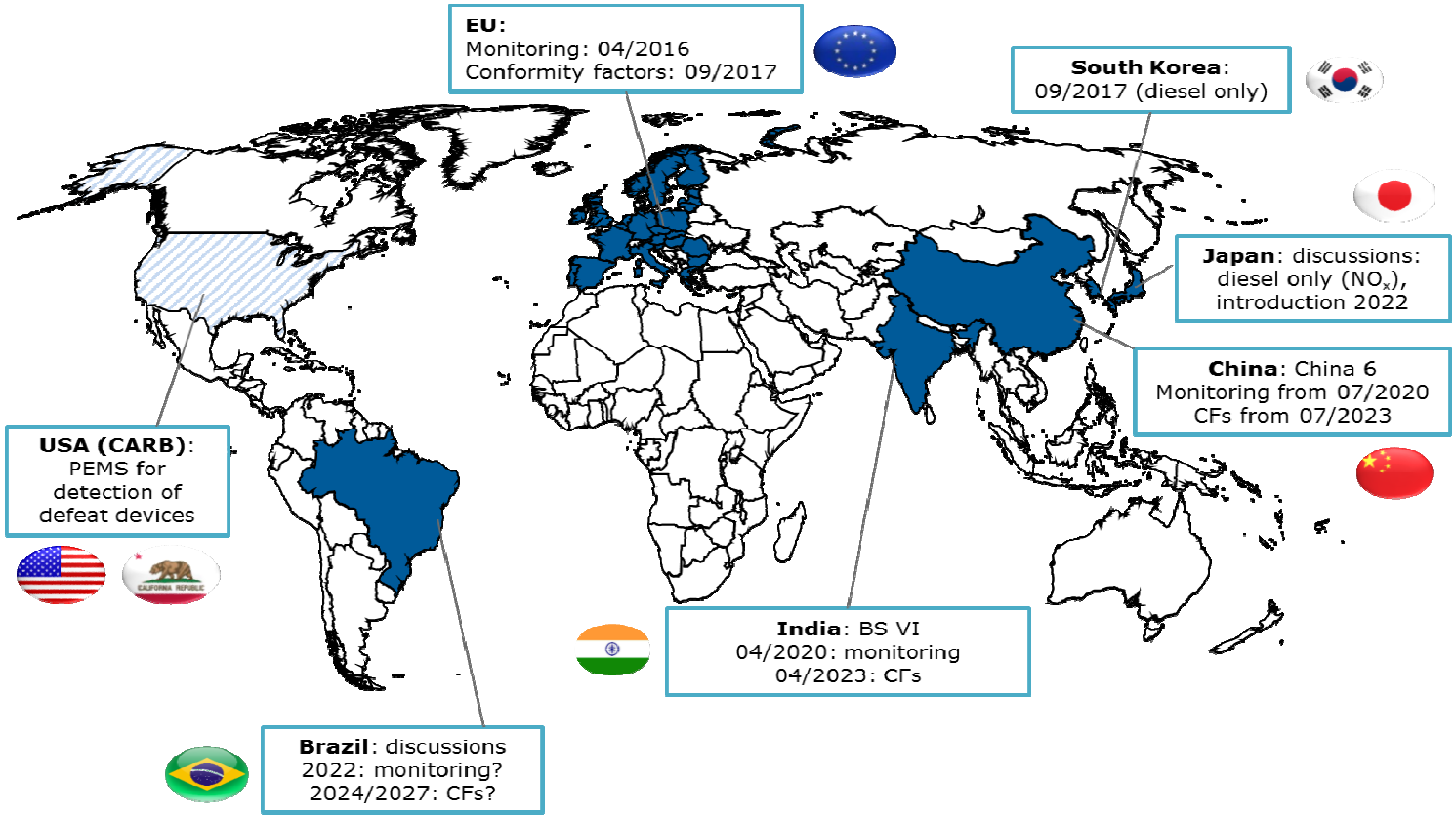


* Note that Japan has already exceeded its 2020 statutory target, as of 2013.

*Proposed Env. Committee EP April 2013

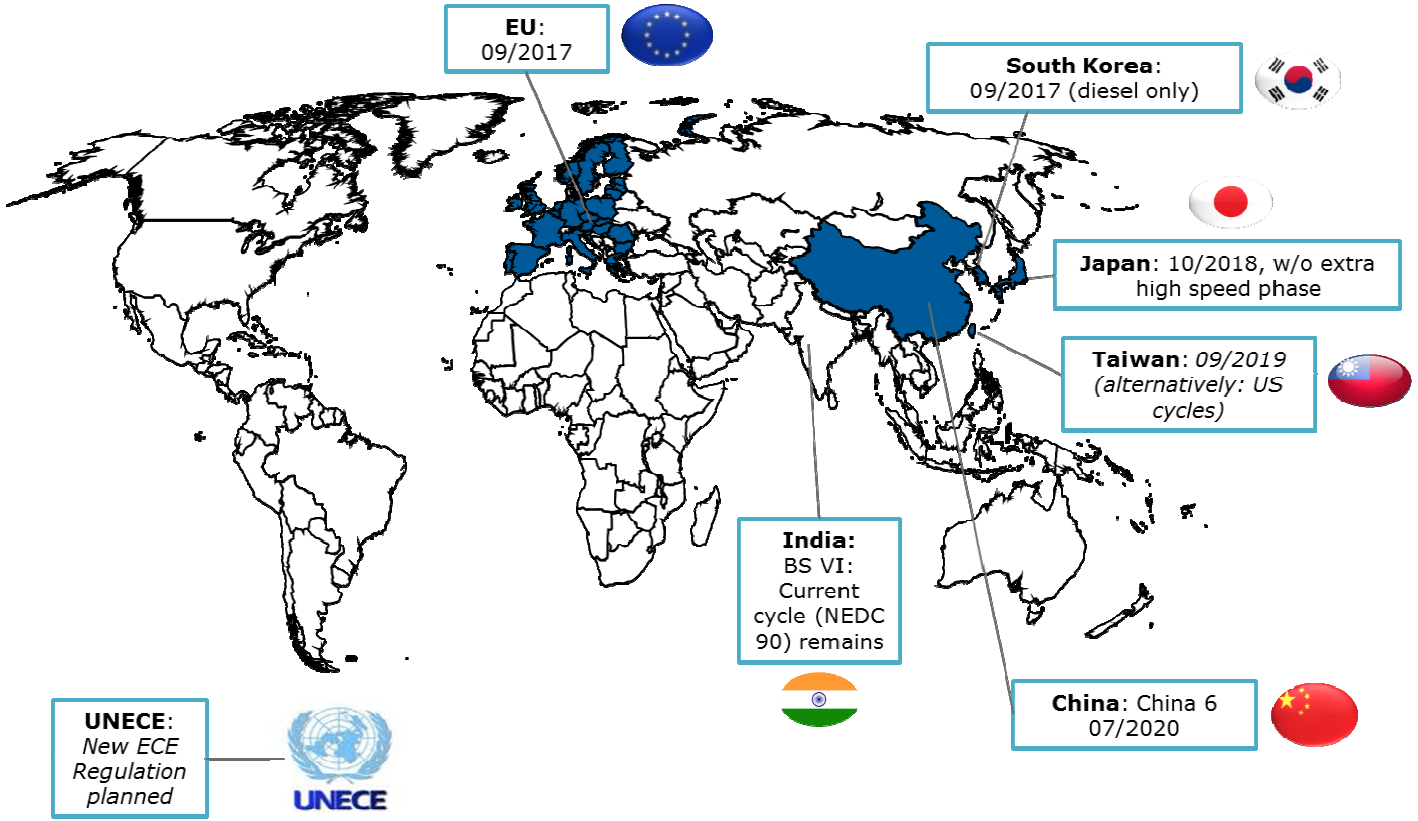
Source: ICCT, 09/2015, www.theicct.org/info-tools/global-passenger-vehicle-standards / AVL

RDE IMPLEMENTATION WORLDWIDE



Status: 07/2017

WLTP IMPLEMENTATION WORLDWIDE



Italics: draft/proposed; dates for new type approval

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CHINA 6 REGULATION
NEW CHALLENGE

- China 6 implementation

	New types	New vehicles
6a	July 1, 2020	July 1, 2020
6b	July 1, 2023	July 1, 2023

- Regions/cities (e.g. Beijing) may enforce China 6a or 6b earlier

- Test procedure: WLTP 4 phases, Vehicle Class 3
  - Significantly more stringent than Euro 6d
  - Low temperature requirements
  - Evaporative requirements
  - Extended RDE

CHINA 6 REGULATION TYPE I (EXHAUST EMISSIONS)

Cycle: WLTC 4 phases; Class 3

Limits (fuel neutral):

	CO	THC	NMHC	THC+NO_x	NO_x	PM	PN	N_2O
	(mg/km)						(#/km)	(mg/km)
China 6a	700	100	68	-	60	4.5	$6x10^{11}$	20
China 6b	500	50	35	-	35	3.0	$6x10^{11}$	20
Euro 6d								
Euro 6d SI	1000	100	68	-	60	4.5	$6x10^{11}$	-
Euro 6d CI	500	-	-	170	80	4.5	$6x10^{11}$	-
Compared to Euro 6d								
China 6b/SI	-50%	-50%	-49%	-	-42%	-33%	0	China only
China 6b/CI	0	China only	China only	-59%*	-56%	-33%		

*** Compared to the sum of China 6b THC and NO_x limit**

CHINA 6 REGULATION TYPE II (RDE)

- CFs mandatory with 6b limits

CF	NO_x		PN		CO	
	Euro 6d	China 6b	Euro 6d	China 6b	Euro 6d	China 6b
Gasoline	1.5	2.1	1.5	2.1	-	
Diesel	1.5	2.1	1.5	2.1	-	

- RDE requires measurement and recording of CO emission
- Before 01 July 2022: reevaluation of CFs planned
- Before 01 July 2023: monitoring and reporting of results

- Compared to EU: additional extended ambient conditions (altitude)

Extended conditions correction factor	700-1,300m		1,300-2,400m	
	EU	China	EU	China
Gasoline	1.6	1.6	Not considered	1.8
Diesel				

CHINA 6 REGULATION TYPE VI (-7°C TEST)

- Limits both for gasoline and diesel
- Cycle: low and medium phases of WLTP

	CO	THC	NO_x
Limits China 6 (g/km)	10.0	1.20	0.25
Euro 6d (gasoline) (g/km)	15.0	1.8	-
Euro 6d (diesel)	-	-	-
Comparison to Euro 6d			
China 6 to Euro 6d (gasoline)	-33%	-33%	China only
China 6 to Euro 6d (diesel)	China only	China only	China only

CHINA NEV REQUIREMENTS

The regulation applies to car makers that produce or import more than 30 000 conventional vehicles annually. If automakers fail to achieve the quotas, they will either have to buy credits from other companies or face a fine.

2019: 10%

2020: 12%

2020+: tbd by MIIT

Vehicle type	Standard model points	Remarks
Pure electric passenger car	0.012×R+0.8	(1) R is the electric vehicle driving range (working method), the unit is km. (2) P is the rated power of the fuel cell system, in kW. (3) The upper limit of the standard model is 5 points. (4) vehicle model calculation results by the principle of rounding to retain two decimal places.
Plug-in hybrid passenger cars	2	
Fuel cell passenger car	0.16×P	

Source: “MECA Global Emissions Bulletin October 2017”, http://www.miit.gov.cn/n1146290/n4388791/c5826378/content.html

AVL POWERTRAIN ENGINEERING TECHDAY #4
EMISSION REGULATION UPDATE

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BASE FOR AVL ASSUMPTIONS FOR EURO 7

Update -7° C Test:

Vehicles: ICE, OVC-HEV, NOVC-HEV
Pollutants: THC, NO_x, CO, CO2 and PN
Auxillary Devices On: Heater, defrost and light

European Parliament-Recommendation (April 2017):

16. … considers that for particulate matter **PEMS technology** should be able to account for **particles** whose size is **smaller than 23 nanometres** and that are the most dangerous to public health;

73. Calls on the Commission to **review the emissions limits** set out in Annex I to Regulation (EC) No 715/2007 with a view to **improving air quality** in the Union and to **achieving the Union ambient air quality limits** as well as the **WHO recommended levels**, and to come forward by **2025** at the latest with proposals, as appropriate, for new **technology-neutral Euro 7 emission limits** applicable for all M1 and N1 vehicles placed on the Union market;

Source: "Inquiry into emission measurements in the automotive sector – European Parliament recommendation of 4 April 2017 to the Council and the Commission following the inquiry into emission measurements in the automotive sector (2016/2908(RSP))"

Progress Report Low and Realistic Winter Temperature TF WLTP 20th-September 2017C. JRC, Astorga

AIR QUALITY
EU DIRECTIVE & WHO GUIDELINE

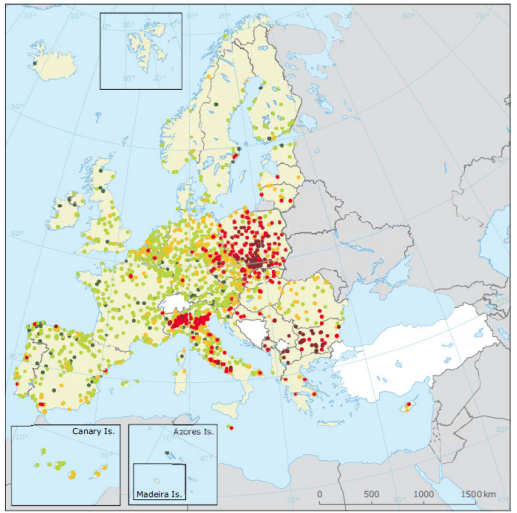
Limited substances within Annex XI of EU Air Quality Directive 2008/50/EC:

$PM_{2.5}$, SO_2, NO_2, PM10, Lead, CO, Benzene, Ozone, Arsenic, Cadmium, Nickel, Polycyclic Aromatic Hydrocarbons

Comparison of limit values for different substances (bold = WHO more stringent)

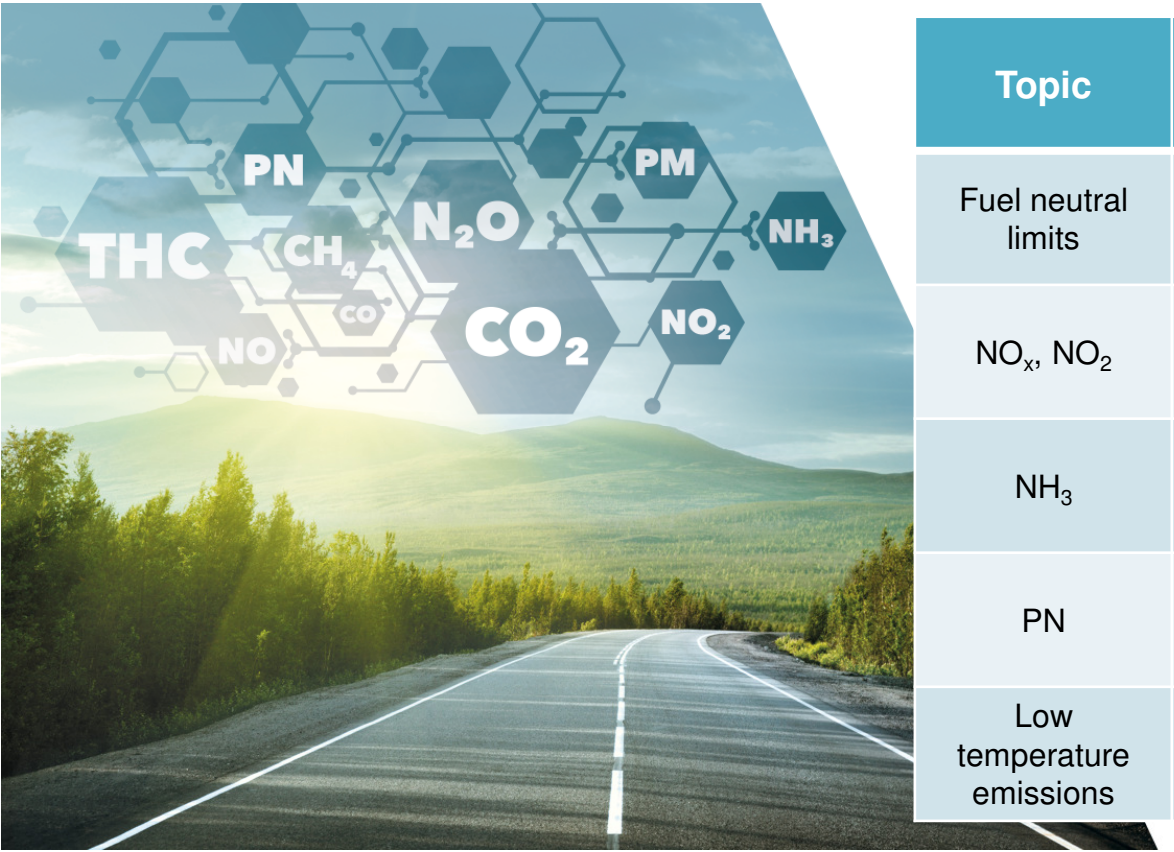
Substance	Limit values (EU)[1]	Limit values (WHO AQG)[2]
Ozone	120 µg/m³ 8-hour mean[a]	**100 µg/m³ 8-hour mean**
SO_2	350 µg/m³ 1-hour mean	500 µg/m³ 10-minute mean
	125 µg/m³ 24-hour mean	**20 µg/m³ 24-hour mean**
NO_2	200 µg/m³ 1-hour mean	200 µg/m³ 1-hour mean
	40 µg/m³ annual mean	40 µg/m³ annual mean
Benzene	5 µg/m³ annual mean	5 µg/m³ annual mean
CO	10 mg/m³ 8-hour mean	10 mg/m³ 8-hour mean
Pb	0.5 µg/m³ annual mean	-
PM_{10}	50 µg/m³ 24-hour mean	50 µg/m³ 24-hour mean
	40 µg/m³ annual mean	**20 µg/m³ annual mean**
$PM_{2.5}$	25[b] (20[c]) µg/m³ annual mean	**10 µg/m³ annual mean**
	-	25 µg/m³ 24-hour mean

PM_{10} concentration.
Red: above EU limit value



[1] EU DIRECTIVE 2008/50/EC
[2] WHO Air quality guidelines, *Global update 2005*
[a] Longterm objective
[b] Stage 1 - Date by which limit value is to be met: 1 January 2015
[c] Stage 2 - Date by which limit value is to be met: 1 January 2020

EU: POSSIBLE FURTHER DEVELOPMENT (I)



Topic	Measures
Fuel neutral limits	same limit for gasoline & diesel
NO_x, NO_2	Reduction NO_x limit, implementation of NO_2 limit
NH_3	Implementation of NH_3 limit, SCR technology, HD applications already limited
PN	Revision of measurement procedure, including of ultrafine particles (size > 10 nm)
Low temperature emissions	Emission limits for PI and CI vehicles (- 7°C), additional components

EU: POSSIBLE FURTHER DEVELOPMENT (II)

Topic	Measures
RDE	Reduction of CF (Target CF=1 in 2023) General evaluation
CO_2	Definition of 2025 targets, proposal November 2017 awaited
CH_4, N_2O	Limitation
CO_2 GHG	Consideration of upstream CO_2 emissions – long term
Air Quality	Extension of Low Emission Zones and access restrictions
Electrification	Promotion of PHEVs and EVs

DERIVATION OF EURO 7-SCENARIO
COMPARISON OF STANDARDS & ASSUMPTION

	Dura-bility (km)	Test Cycle	NMOG+ NO_x (mg/km)	THC (mg/km)	NO_x (mg/km)	NO_2(mg /km)	THC+ No_x (mg/km)	NMHC (mg/km)	CO (mg/km)	HCHO (mg/km)	PM (mg/km)	PN (#/km)	N_2O (mg/km)	CH_4 (mg/km)	NH_3 (ppm)	RDE
SULEV 30	241,402	FTP 75	18.64	-	-			-	621	18.64	6.21	-	6.21	18.64	-	-
SULEV 20			12.43								2025+: 0.621					
China 6b	200,000	WLTP	-	50	35			35	500	-	3.0	$6x10^{11}$	20	-		CF=2.1
	• -7°C-Test: fuel neutral; limits for CO, THC and NO_x, via low and medium phases of WLTP • RDE extended ambient conditions: altitude up to 2,400m															
Euro 6d SI	160,000	WLTP	-	100	60		-	68	1000	-	4.5	$6x10^{11}$	-	-		CF=1.5
Euro 6d CI		WLTP	-	-	80		170	-	500	-	4.5	$6x10^{11}$	-	-		CF=1.5
WLTP GTR15	• Sampling and analysis methods for NH_3, N_2O, ethanol, formaldehyde and acetaldehyde (if applicable)															
Euro 7*	200,000	WLTP	-	50	35	20	-	35	500	-	3.0	$6x10^{11}$	?	?	10	CF=1
	• -7°C-Test: fuel neutral; limits for CO, THC, NO_x, PN and CO_2 via low and medium phases of WLTP • RDE revised procedure and normalization tools										• PN: > 10 nm					

*AVL Assumption

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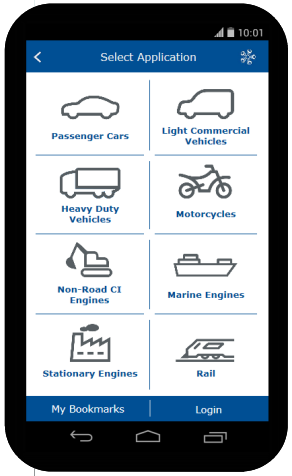

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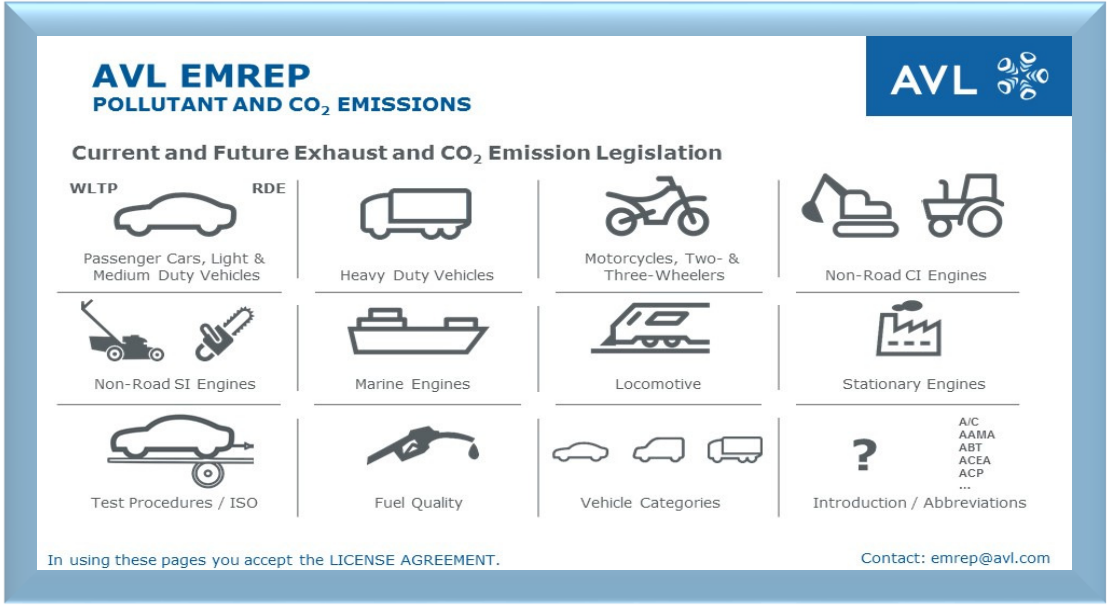
AVL EMISSION REGULATION REPORT



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