AVL List GmbH (Headquarters)

Emission Regulation Trends

AVL Emission TechDay 2018, Mattsee, Österreich

Engeljehringer, Kurt

Notes

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Project Leader:	
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Customer:	
Project:	
Task ID:	
Department:	Emission Test Systems

Content

Euro-5 and Euro 6 Legislation

REGULATION (EC) No 715/2007 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

Article 4 - Manufacturers' obligations

... the technical measures taken by the manufacturer must be such as **to ensure that the tailpipe and evaporative emissions are effectively limited**, pursuant to this Regulation, **throughout the normal life of the vehicles under normal conditions of use**.

Article 5 – Requirements and tests

The use of defeat devices ... shall be prohibited. The prohibition shall not apply where:

- **the need is justified for protecting the engine against damage**
- the device does not function beyond engine starting, or
- the conditions are included in the test procedures ...

Article 13 – Penalties

Member States shall lay down the provisions on **penalties** applicable for infringement by manufacturers of the provisions of this Regulation and **shall take all measures necessary to ensure that they are implemented. The penalties provided for must be effective, proportionate and dissuasive.**

Before: 1 vehicle was tested in a 20min NEDC test

+ 10 min since WLTC Test, (one test less per shift)

+ 1 more vehicle, CO_2low and CO_2high

+ 30min Ambient Temperature Correction Test 14°C

+ 90min RDE cold test

+ 90min RDE warm test

= app. 15 times more work load of testing

9/2017
New type approvals

Euro 6d-TEMP

9/2019
Last date of registration

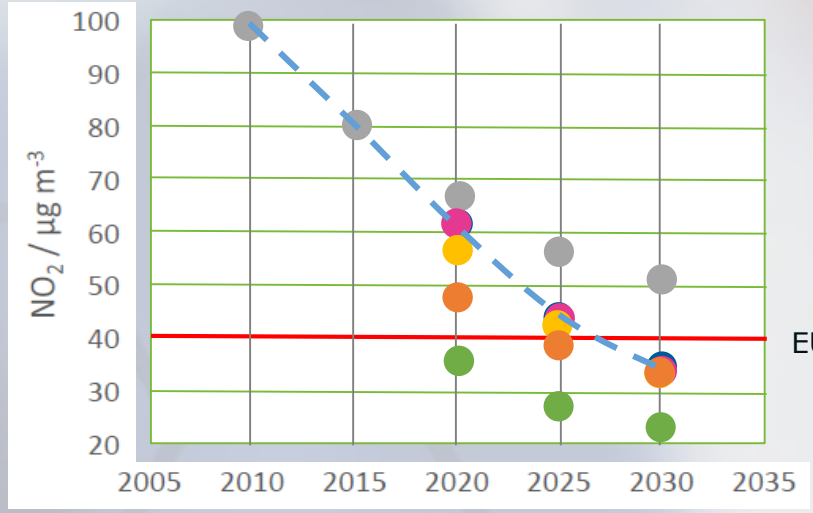
STOP

STOP

Local driving restrictions

UBA: NO2 Reduction scenarios

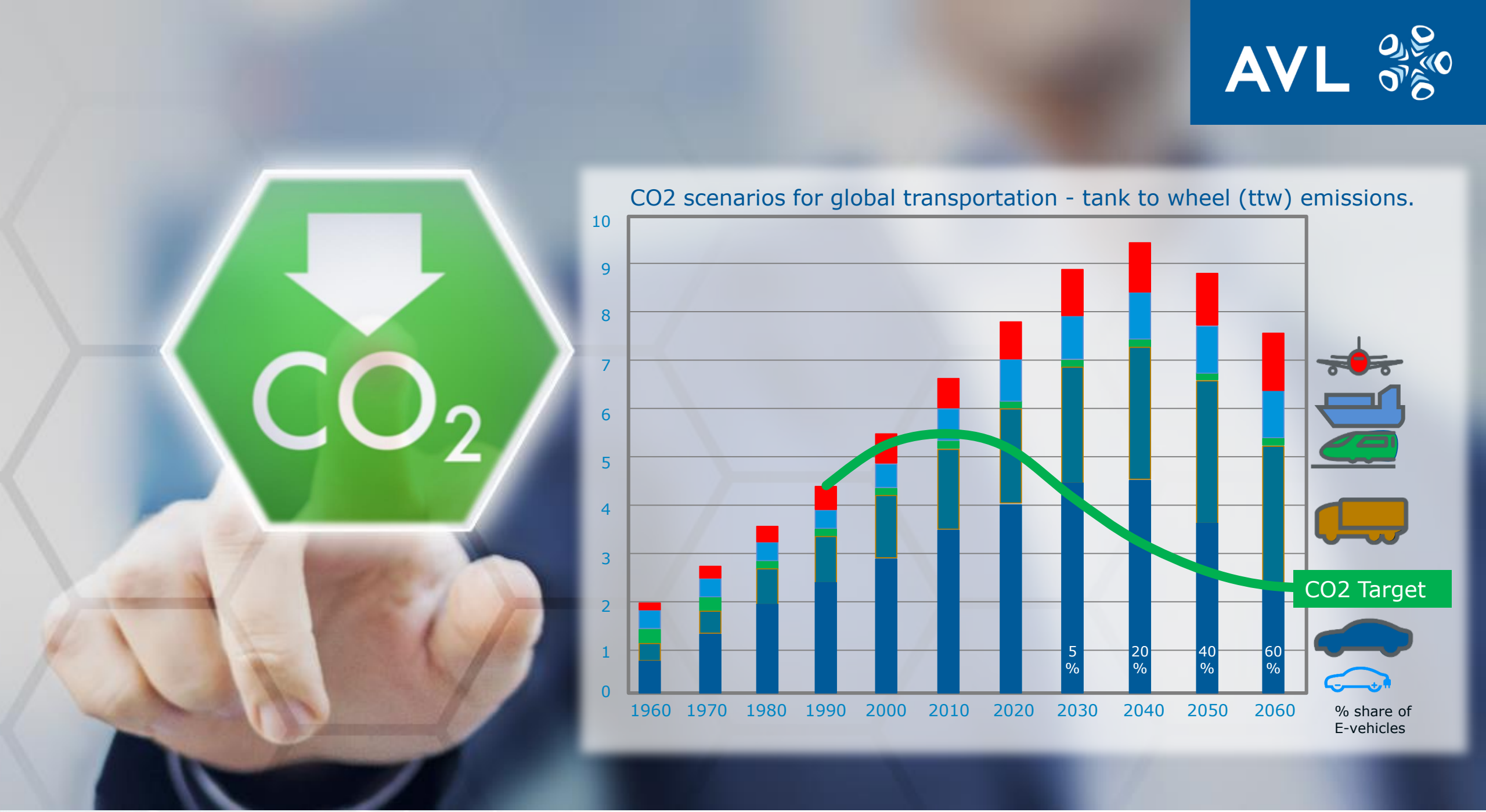
Landshuter Allee in Munich



EU NO2 Immissions Limit (2008/50/EG)

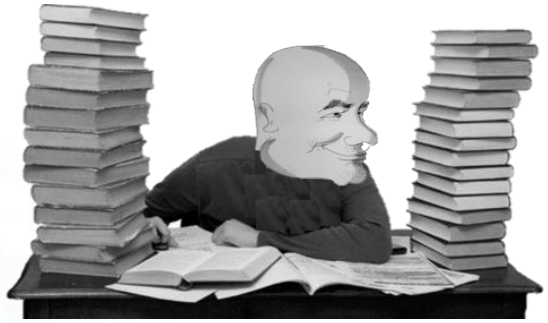
- EU-6 without RDE
- EU-6 d temp with Real Driving Emission (RDE)
- Electrification of public transportation
- Strong share of e-mobility
- Environmental zones for trucks
- Next level environmental zones
- **Ban of Diesel**

Source: UBA Lars Mönch, Martin Lange; Fortschreibung der RDE Gesetzgebung und damit verbundene Herausforderungen, FAD RDE-Workshop, Dresden 2016


CO2 scenarios for global transportation - tank to wheel (ttw) emissions.
10
9
8
7
6
5
4
3
2
1
0
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
5 %
20 %
40 %
60 %
CO2 Target
% share of E-vehicles

- Introduction
- **Tail pipe emission legislations:**
  - Light Duty
  - Heavy Duty
  - Non-Road
- Evaporative Emissions
- CO2 emission reduction
- Future Mobility

UNECE/EU Light Duty Evolution & Revolution



20 pages

180 pages

800 pages

RDE
180 pages

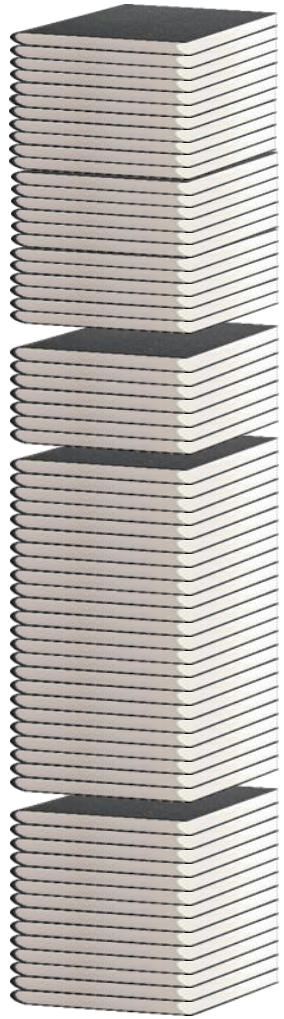
GTR-15 (WLTP)
350 pages

ECE R83.07
270 pages

643 pages

RDE
European-WLTP
UNR-83

1380 pages



RDE 4 and
WLTP 2
420 pages

RDE 3
47 pages

GTR-15
RDE 1+2

UNR 83.07
270 pages

1970 Euro-0	2005 Euro-4	2017: UNR-83 + GTR-15 + RDE	2017: EU-6d-temp	2018+

Fastest ever legislation implementation

Country	Topic	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
	Limits	Euro 6b				Euro 6d temp		Euro 6d	?		? *Euro 7*	
	CO_2	130 g/km CO_2							95 g/km CO_2			-15%
	Tech. Reg	UN-ECE Reg. 83				EU 2017/1151 (WLTP)						
	EVAP						Euro 6d-temp-EVAP					
	RDE			Monitor		NOx 2.1, PN 1.		RDE CF NOx < 1.5, CF PN 1.5				
	ISC						New procedure incl. RDE, EVAP, -7°C					

Very fast changes
Last-Minute amendments

For a new Euro-7 legislation the whole formal and political decision process must be passed

Euro-6a,b,c,d,e,f,g,h,i,j, ... can be done quickly and without politics.

March 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

Emission legislation – passenger cars

Country	Topic	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Notes
EU	Limits	Euro 5b				Euro 6b				Euro 6d-TEMP	Euro 6d	?		? Euro 7		01/2019: **Euro 6d-TEMP-ISC**, 09/2019 Euro 6d-TEMP-EVAP
	RDE					Monitor		RDE NOx + PN		RDE CF* NOx 1.43, CF PN 1.5						Eu-6d-TEMP: RDE CF NOx 2.1, PN 1.5
	CO_2/FC	130 g/km CO_2												95 g/km CO_2 (NEDC based)	-15%	2021: WLTP based target, 2025: 2021 average -15%
	Tech. Reg.	UNR 83 (NEDC)						EU 2017/1151 (WLTP)								
US	EPA	US-EPA – Tier 2					US-EPA – Tier 3									Fuel neutral limits
	CARB	US-CARB – LEV II				US-CARB – LEV III, phase in of 1 mg/mi PM standard 2025-2028										Fuel neutral limits
	RDE															PEMS used for detection of defeat devices
	CO_2/FC	GHG (2012-2016) 263 -> 225 g CO_2/mi					GHG (2017-2025) 212 -> 143 g CO_2/mi									GHG limits in addition to CAFE, **under review**
	Tech. Reg.	40 CFR PART 86								40 CFR PART 1066						
China	National	China 4					China 5			China 6a			Ch 6b: Eu6 - 50%			China 6: Fuel neutral limits
	Beijing	Beijing 5								China 6b ?						
	RDE									Monitor			RDE CF NOx and PN 2.1			Altitude 0-700-1300-2400m
	CO_2/FC	Fuel Consumption Stage 2				6.9 l/100km (161 g CO_2/km)				Stage 4: 5 l/100km (117 g CO_2/km) , NEDC					Stage 5	Stage 5: 4l/100km in 2025
	Tech. Reg.	GB 18352.3-2005 (NEDC)				GB18352.5-2013 (NEDC)				GB 18352.6-2016 (WLTP)						

*Measurement uncertainty of PEMS equipment to be evaluated annually. CF = 1.0 + measurement uncertainty.
Implementation dates for new types if applicable

Status 05.03.2018

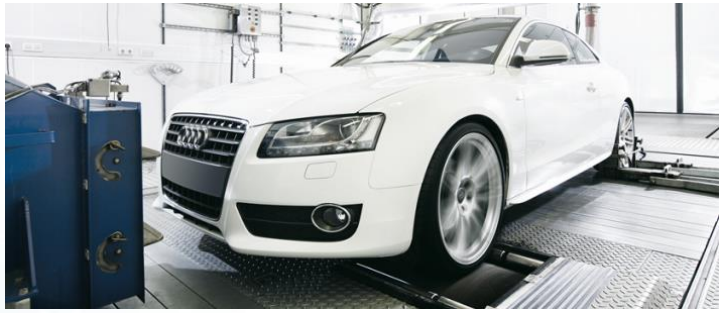
Emission legislation – passenger cars

Country	Topic	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Notes
	Limits	Post New Long Term								Post Post New Long Term						
	RDE											**RDE** CF NOx 2				Diesel only
	CO_2/FC	Fuel Economy Targets				Fuel Economy Targets 2015						Fuel Economy Targets 2020				
	Tech. Reg.	TRIAS (JC08)								TRIAS (WLTP)						
	Limits	K-LEV II, 2014: Euro 6 (Diesel)				K-LEV III (gasoline), Euro 6 (Diesel)										
	RDE							**RDE** CF NOx 2.1		**RDE** CF NOx 1.5						Diesel only
	CO_2/FC	17 km/l or 140 g CO_2/km													24.3 km/l or 97 g CO_2/km	
	Tech. Reg.	40 CFR PART 86 (Gasoline) +UNR 83 (Diesel)						**40 CFR PART 1066 (Gasoline) and WLTP (Diesel)**								
	National	Bharat III					Bharat IV			Bharat VI						
	Cities	Bharat IV								Bharat VI						
	RDE									Monitor		**RDE** (CF tbd)				
	CO_2/FC					5.5 l/100km (130 g CO_2/km)						4.7 l/100km (113 g CO_2/km)				
	Tech. Reg.	MoRTH / CMVR / TAP-115/116 (Indian Driving Cycle v_{max} = 90 km/h), AIS137														in future (?) WLTP
ASEAN	Limits	Euro 2 ... 4 … 6													?	
	Tech. Reg.	UNR 83														in future (?) WLTP

Implementation dates for new types if applicable

Status 08.02.2018

CO2 Testing requirements (EU)



CO2 tested for a "CO2 Low" and "CO2 High" vehicle configuration

CO2 emission has to be tested for a vehicle expected to have the lowest CO2 and for a vehicle expected to have the highest CO2-Emission, per vehicle family.
Individual vehicle CO2 emissions can be interpolated.

CO2 targets (130g/km, 95g/km) are still based on NEDC and UNR-83 testing

For pollutant emissions WLTC with WLTP have to tested and for CO2 OEM may chose to:

- run separately NEDC for CO2 emissions, or
- to predict NEDC result from the WLTC test data, by using the CO2mpas tool from JRC, to reduce testing burden.

14°C ATCT

Ambient Temperature Correction Test at 14°C (for EU)

WLTC	at 14°C with for 14°C corrected road load dyno parameters
Soak area:	14°C Trep ± 3°C (1Hz data as 5min running average)
Soak Time:	Preconditioning → max 10min to Soak area for min 9h → ATAC
Test cell:	14°C Trep ± 3°C at test start and ±5°C during test (1Hz)
Intake air humidity:	3.0 ≤ H ≤ 8.1 g H2O/kg dry air
Family Correction Factor:	FCF = CO2 Type-I@14°C / CO2 Type-I@23°C
Individual vehicle CO2:	CO2_ind = CO2_ind@23°C × FCF

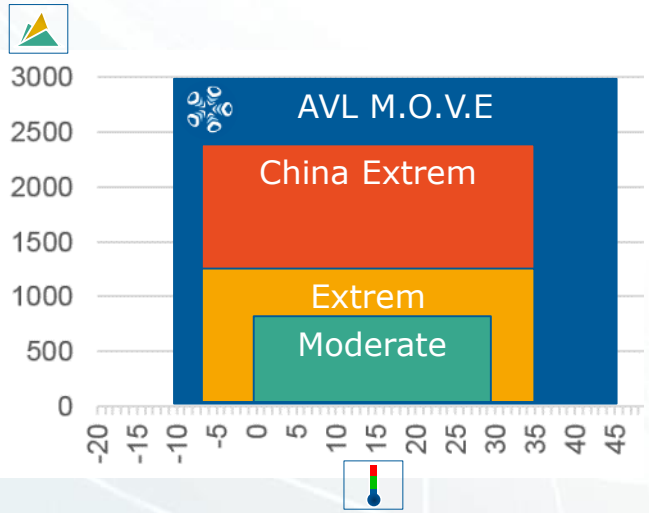

RDE

Technical Regulations: RDE

Application

Standard

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



Light duty vehicle on Real Driving Emission testing:

- Portable Emission Measurement System (PEMS) to measure CO2, CO, NOx, PN, Exhaust flow, Speed and GPS data.
- Implementation: EU 2016, Korea 2018, China 2019, India 2020, Japan 2021

Limits:

- CF NOx: 2.1 → 1.5 CF PN: 1.5 → 1.x (in discussion)
- 2 calculation options, EMROAD (JRC) or CLEAR (TU-Graz)

RDE Test requirements:

- 30min conditioning drive, 5-56h soak time, cold test and hot start test
- RDE Drive between 90 to 120min in normal traffic.
- 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

Ambient conditions:

- 0°C to 30°C (extended range -7°C to 35°C)
- up to 700m (extended range 1300m) (China 2400m)

Light-Duty Emission LAB 2.0

Old Emission Lab

Soak Area: Temperature Conditioning

Chassis Dyno: Emission Test

ICE Vehicles + RDE

Temperature → RDE

Plug-In Hybrids

Temperature, Charging energy → RDE

Battery E-Vehicles

Temperature, Charging energy → E

Fuel Cell E-Vehicles

Fuel Cell → FC

Since 50 years a vehicle was temperature conditioned and afterwards an emission test cycle was done. (1966 CARB Test procedure)

RDE extends emission testing to real driving conditions on the road.

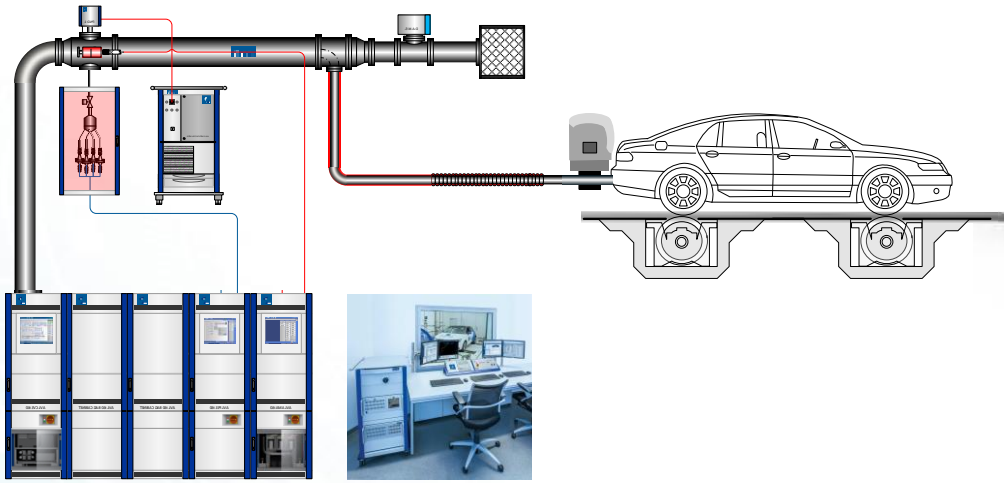
Electrification extends emission testing into the Soak area, which becomes part of the measurement

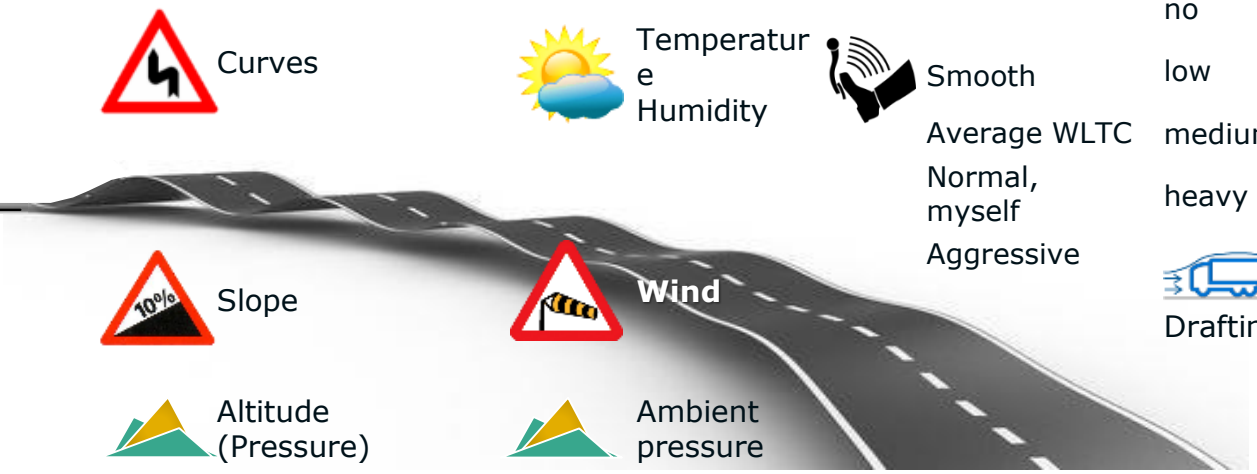
E-Vehicles must also run a regular emission test cycle (Energy consumption and driving range measurement)

Fuel-Cell Vehicles must also run a regular emission test cycle for H2 consumption evaluation

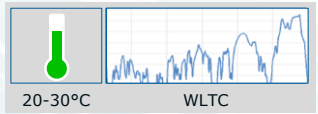
Emission Legislation: EU versus US

CVS + AMA + PSS + APC | Automation | PEMS | Chassis Dyno | Street | Ambient Conditions | Driver | Traffic





Lab. Certification + OBD + COP + ISC + I/M — since 2017

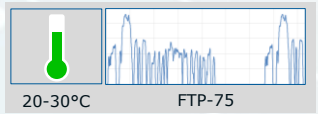


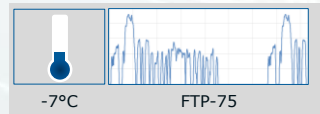
only Gasoline

BES/AES Documentation

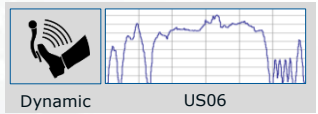
Euro-6d: Real Driving Emissions (Not to exceed limits)

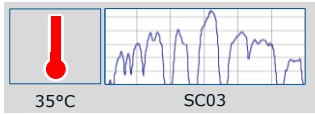
Lab. Certification + OBD + COP + ISC + I/M — PEMS

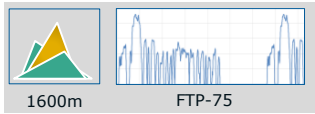




only Gasoline







„Look into ECU"

RDE used to chase "Defeat Devices"

GTR 15 amendments und RDE4/WLTP2

Amendment 3 (enforced): (355 pages)

- 01_UN_ECE_gtr_15_WLTP_amendment_3_2018-02-01

Amendment 4 (proposal): (358 pages)

- 04_UN_ECE_gtr_15_proposal_for_amendment_4_2017-10

Draft RDE4/WLTP2: (421 pages)

- 001_draft_Commission_Regulation_RDE4_WLTP2_2018-03-03
- **In-Service conformity procedure** with new emissions standard Euro 6d-TEMP-ISC, performed by granting type approval authority, OEM or 3rd parties with accredited laboratories
  - 01.01.2019 for new types and 01.09.2019 for new vehicles
  - WLTP tests
  - RDE tests
  - EVAP tests
  - -7°C tests
- details on AES documentation and assessment

- RDE package 4
  - new uncertainty margin for NOx CF of 0.43 (CF NOx=1.43)
  - Removal of CLEAR tool and modified EMROAD used for verification of trip validity
  - New emissions calculation method (new Appendix 6)
  - Removal of Appendix 7c (evaluation for plug-in hybrids), including plug-in hybrids into emissions calculation method
  - a number of clarifications and smaller modifications
- **WLTP based evaporative emissions test procedure**
- amendments to OBD requirements (Annex XI)
- requirements for vehicles that use a reagent for EAS
- implementation of amendments 3 and 4 to UN GTR 15 into EU WLTP
- Introduction of devices for on-board fuel consumption monitoring

Guidance on AES and Defeat Devices

EC 715/2007 Evaluation of Auxiliary Emission Strategies and Defeat Devices)

EUROPEAN COMMISSION

26.1.2017

Brussels, 26.1.2017
C(2017) 352 final

COMMISSION NOTICE

of 26.1.2017

Guidance on the evaluation of Auxiliary Emission Strategies and the presence of Defeat Devices with regard to the application of Regulation (EC) No 715/2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6)


Remote Sensing


Vehicle Chasing


SEMS


Chassis Dyno


RDE


EVAP Emission

Extended documentation package (since May 2016)

- Manufacturer declaration that the vehicle does not contain any defeat device
- Extended BES/AES description
- Software versions and checksums

Evaluation and acceptance of AES

- AES for engine protection is limited to "catastrophic" engine damages and if better technologies are available it shall be used
- Check of parameters used to modulate emission control systems
- Check for EGR modifications (only under certain conditions)
- Check if intentional shifting of particle size below 23 nm, so it is not measured
- Check dual injection systems for gasoline vehicles that were not type approved as GDI

Defeat device recognition for member states surveillance testing (JRC proposal)

- Vehicle selection based on market share.
- "It is worth noting that ... also includes other types of emissions tests such as Evaporative emissions"

Screening the environmental performance

- Remote fleet monitoring with "Simplified Emissions Measurement Systems" (SEMS)
- Remote Sensing Devices (RSD) at fixed locations or as chasing test

Testing for Defeat Devices (with the need to keep a non-predictable character)

- Lab-Test with limited modified test — CF 1.0
- Lab-Test or Road-Test with conditions different than the legislative cycle — CF 1.1
- Road-test with uncontrolled parameters (e.g. RDE compliant testing) — CF 1.5
- "Surprise testing" to detect a defeat device (e.g. including Evaporative emissions) — CF 2 ... 5

→ if any test fails, vehicle is classified as „Suspicious" vehicle

Council of the European Union

reform type-approval and market surveillance system

European Council
Council of the European Union

Car emission controls: Council agrees to reform type-approval and market surveillance system

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29/05/2017 | 11:25 | Press release | 306/17 | Single market | Research & technological development | Environment | Enterprise and industry

The Council agreed on a general approach to reform the system of **type-approval and market surveillance for motor vehicles**.

This major reform will modernise the current system, adapt it to **new technologies** available on the market and improve **control tests on car emissions** data.

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"Public health, air quality and innovation are at the core of this agreement. The only way to restore and increase trust in the European automobile industry is to help to develop clean and safety technologies. Reliable control tests for cars will be established so that emission irregularities that happened in the past cannot reappear in the future", said Chris Cardona, Chair of the Council and Minister for the Economy, Investment and Small Business of Malta.

The aim of the reform is to achieve a high level of safety and **environmental performance** of motor vehicles and to address the main shortcomings identified in the existing type-approval system.

The Council general approach will have to be negotiated with the European Parliament before becoming law. The Parliament voted its position on 4 April.

Important changes will be introduced in three areas by strengthening:

- the **quality of testing** that allows a car to be placed on the market through improved technical services
- **market surveillance** to control the conformity of cars already available on the market, with the possibility for member states and the Commission to carry out **spot-checks on vehicles** in order to detect failures at an early stage
- the **oversight of the type-approval process**, in particular through the establishment of a Forum for the exchange of information on enforcement, made up of representatives of national approval and market surveillance authorities

Council agrees to reform type-approval and market surveillance system (May 2017)

- Public health, air quality and innovation are at the core of this agreement.
- The only way to restore and increase trust in the European automobile industry is to help to develop clean and safety technologies.
- Reliable control tests for cars will be established so that emission irregularities that happened in the past cannot reappear in the future.

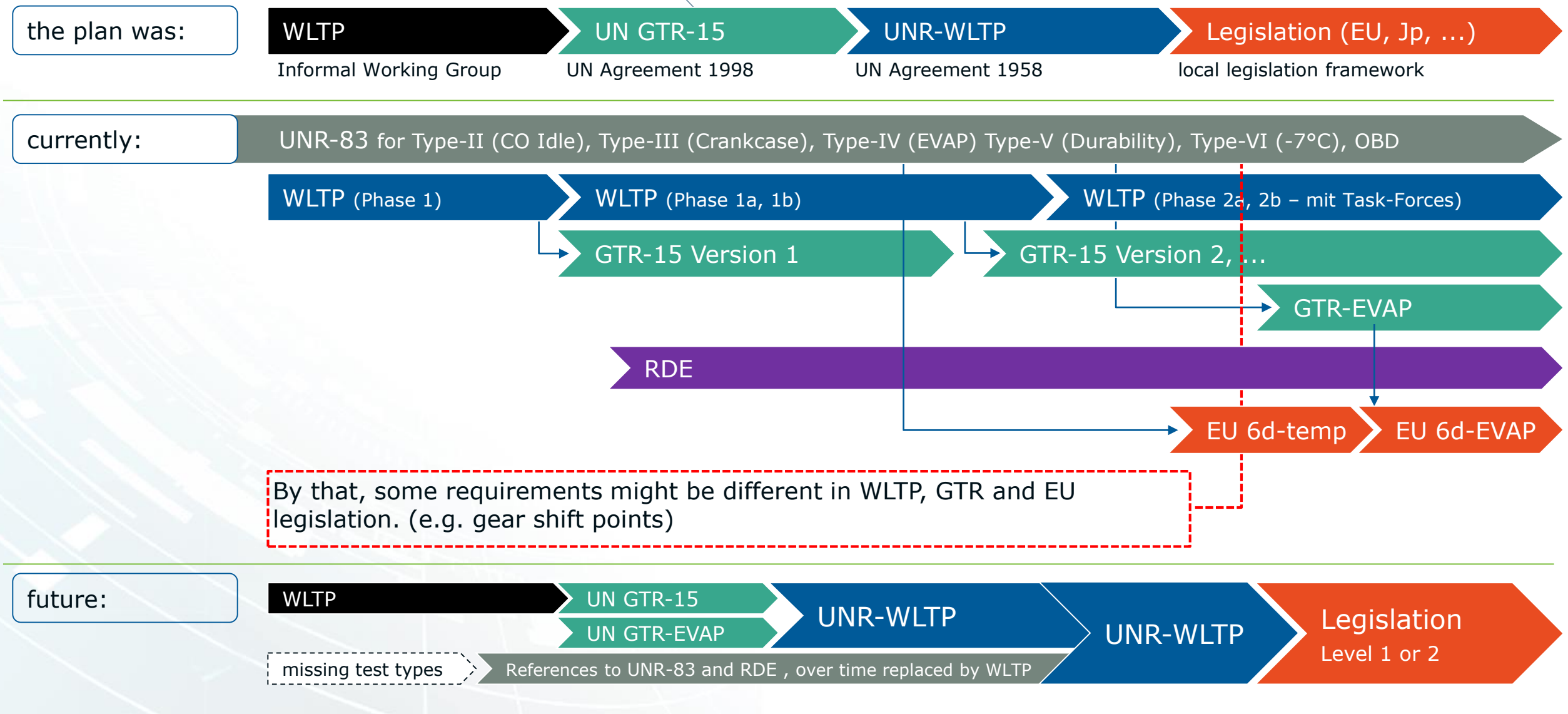
Important changes will be introduced:

- Quality of testing that allows a car to be placed on the market through improved technical services
- Market surveillance to control the conformity of cars already available on the market, with the possibility for member states and the Commission to carry out spot-checks on vehicles.
- Oversight of type-approval process:
    - Technical services will be regularly and independently audited
    - National type-approval authorities will be subject to Commission audits

Market surveillance

- Mandatory market surveillance of a least 1 out of every 50,000 new registered cars per country and year.
- €30 000 (up to) fines by EU Commission on manufacturers per non-compliant vehicle.
- The checks will include verification of emissions under real driving conditions.

From WLTP to local Legislation



Introduction

Tail pipe emission legislations:

- Light Duty
- Heavy Duty
- Non-Road

Evaporative Emissions

CO2 emission reduction

Future Mobility

Emission Measurement

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
PN measurement
off-cycle emissions

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

Eu-4 and EU-5 Standards

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

Introduction of PM limits for CI and GDI engines, only

Vehicle Category	Vehicle Category Name	Propulsion Class	Mass of [mg/km] CO	THC	NOx	PM		Test Cycle
			L_1	L_2	L_3	L_4		
L1e-A	Powered cycle	PI/CI/Hybrid	560	100	70	-		ECE R47
L1e-B	Two-wheel moped	PI/CI/Hybrid	1.000	630	170	-		ECE R47
L2e	Three-wheel moped	PI/CI/Hybrid	1.900	730	170	-		ECE R47
L3e [1)] L4e	Two-wheel motorcycles with and without side-car	PI/CI/Hybrid v_{max} < 130 km/h	1.140	380	70	-		WMTC, Stage 2
L5e-A L7e-A	Tricycle Heavy on-road quad	PI/CI/Hybrid v_{max} ≥ 130 km/h	1.140	170	90	-		WMTC, Stage 2
		CI/CI/Hybrid	1.000	100	300	80		WMTC, Stage 2
L5e-B	Commercial tricycle	PI/PI/Hybrid	2.000	550	250	-		ECE R40
		CI/CI/Hybrid	1.000	100	550	80		ECE R40
L6e-A	Light on-road quad	PI/PI/Hybrid	1.900	730	170	-		ECE R47
L6e-B	Light quadrimobile	CI/CI/Hybrid	1.000	100	550	80		ECE R47
L7e-B	Heavy all terrain quad	PI/PI/Hybrid	2.000	550	250	-		ECE R40
L7e-C	Heavy quadrimobile	CI/CI/Hybrid	1.000	100	550	80		ECE R40

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

open discussion until 2017 (Effect study) in-use conformity, off-cycle emissions and PN

Vehicle Category	Vehicle Category Name	Propulsion Class	Mass of [mg/km] CO	THC	NHMC	NOx	PM [2)]	Test Cycle
			L_1	L_{2A}	L_{2B}	L_3	L_4	
L1e-A	Powered cycle	PI/CI/Hybrid	500	100	68	60	4,5	Revised WMTC [3)]
L1e-B-L7e	All other L-category vehicles	PI/PI/Hybrid	1.000	100	68	60	4,5	Revised WMTC
		CI/CI/Hybrid	500	100	68	90	4,5	Revised WMTC

Source: Delphi worldwide emissions standards PC-LDV

USA Standards

USA: EPA Motorcycle Standard [g/km]

Year	Class	Disp. (cc)	HC corp. ave	CO	HC+NOx	
					corp. ave	max
06+	I	50-169	1,0	12		
06+	II	170-279	1,0	12		
06-09	III	≥ 280	1,0	12	1,4	5,0
10+	III	≥ 280		12	0,8	5,0

USA: CARB Motorcycle Standard [g/km]

Year	Class	Disp.	HC		CO	HC+NOx	
			corp. ave	max		corp. ave	max
88-03	I & II	50-279	1,0	2,5	12		
88-03	IIIa	280-699	1,0	2,5	12		
	IIIb	700+	1,4	2,5	12		
04-07	III	≥ 280			12	1,4	2,5
08+	III	≥ 280			12	0,8	2,5

Source: Delphi worldwide emissions standards PC-LDV

other Countries

Brazil

Phase-in Requirement - PROMOT 4 /WMTC Cycle - Idle HC & CO - 2009 until 2013: 2.000 ppm of HC revised and 3,5% of CO revised / 2014: 400 ppm of HC revised and 2,0% of CO revised - Fixed Deterioration Factors (DF) from Jan 2014
Annual production < 10.000 units - CO, HC and NOx 20%
Annual production > 10.000 units - Mopeds - DF based on 10.000 km / Motorcycles < 130 km/h - DF based on 18.000 km
Motorcycles > 130 km/h - DF based on 30.000 km

Category		Application Date	Displacement	Limits (g/km)			
				HC	NOx	HC+NOx	CO
Mopeds	New Models	Jan 2014	< 50 cc		0,8	1,0	0,15
Motorcycles and Similar	New Models	Jan 2014	< 130 km/h	0,8	2,0	0,15	
Motorcycles and Similar	New Models	Jan 2014	> 130 km/h		0,3	2,0	0,15

Chile

Santiago — 2009: Euro 2 or US06 — 2010: Euro 3 or US10

China Taiwan

Category	Equivalent to	Cycle	Application Date	Displacement	HC	CO	HC+NOx	CO
2 Wheel	Euro 3	UDC	Jul 2001	< 150 cc	0,8	0,15		2,0
	Euro 3	UDC+EUDC		≥ 150 cc	0,3	0,15		2,0
	Euro 4	WHTC	Apr 2017 t.b.c.					
3 Wheel	Euro 3	UDC	Apr 2005	All	4,0	0,25		1,00
Beijing								
Durability 15.000 km	Euro 3	UN-ECE Reg10	Apr 2010	All			2,00	3,50

India

Standard	Application	Description	Test Cycle	PM	CO	NOx	HC+NOx	
							EVAP [g/test]	
							< 2,0	< 6,0
Bharat III	2010	All 2W	IDC Type1		1		1	1
		3W PI			1,25		1,25	1,25
		3W CI		0,05	0,5		0,5	0,5
Bharat IV	2016 TA: 2017 AV	2W Class1, Subclass 2-1 PI	WMTC		1,403	0,39	0,79	0,59
		2W Subclass 2-2 PI			1,97	0,34	0,67	0,47
		2W Subclass 3-1, 3-2 PI			1,97	0,2	0,4	0,2

Indonesia — UN-ECE Reg 40 Step 3

Japan

Category			Durability	HC	NOx	HC+NOx	CO	
Motorcycle ≤ 125 cc	ISO 6460	ECE R40-cold start	15.000 km	0,5	0,15		2,0	
Motorcycle > 125 cc	ISO 6460	ECE R40-cold + EUDC-cold start	24.000 km	0,3	0,15		2,0	

Singapore — All motorcycles

South Korea

Standard	Application	Description	Test Cycle	CO	HC	NOx	
Euro 2	1 Jan 2008	All 3W	CVS-40	7	1,5	0,4	
Euro 3	1 Jan 2008	2W < 150 CC PI	UDC cold	2	0,8	0,15	
Euro 3	1 Jan 2008	2W > 150 CC PI	ECE40+EUDC	2	0,3	0,15	

Switzerland — Euro 3

Thailand — Euro 3

Vietnam

Standard	Application	Description	Test Cycle	PM	CO	HC	NOx	
Euro 3	1 Jan 2017	2W < 150 CC PI	UDC cold		2	0,8	0,15	
		2W > 150 CC PI	UDC+EUDC cold		2	0,3	0,15	
		3W PI	ECE R40		4	1	0,25	
		3W CI		0,1	1	0,15	0,65	
Euro 5	1 Jan 2022							

Source: Delphi worldwide emissions standards PC-LDV

- Introduction
- **Tail pipe emission legislations:**
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- Future Mobility


ZDF
MERCEDES ACTROS
250
mg/km NOx
643
mg/km NOx
C220
Quelle: TNO

Emission Legislation – Heavy Duty Engines

Country	Topic	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Notes
	Limits	Euro-V		Euro-VI								?	Euro-VII			
	RDE	NOx Screening		**Off-Cycle Emissions**: WNTE Random 15 mode test + In-Service compliance (PEMS)												PN-PEMS planned
	CO2							CO_2 Monitoring & Declaration					?		CO2 Limits ?	
	Tech. Reg.	UN-ECE R-49														
	EPA	US-EPA – US10														
	CARB								CARB optional low NOx				Mandatory low NOx?			
	RDE	**Not to Exceed (NTE) testing with PEMS**														
	CO2	**GHG & Fuel Economy – US Phase I**									**GHG Phase II**					
	Tech. Reg.	**CFR-1065**														
	National	China IV					China V				China VI					
	Beijing	China IV				China V				?	China VI					
	RDE					**Beijing NOx**		**ISC with PEMS**								
	CO2			**Fuel consumption Stage 2**							**Fuel Consumption Stage 3**					WHVC on a chassis dyno
	Tech. Reg.	**UN-ECE Reg. 49**									**GB17691-201x**					

Emission Legislation – Heavy Duty Engines

Country	Topic	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Notes
	Limits	PNLT					Post PNLT									
	CO_2				Fuel Efficiency 2015										2025	
	Limits	Euro V		Euro VI									?	Euro VII		
	CO_2									Fuel Consumption ?						
	Limits	Bharat III					Bharat IV			Bharat VI						Bharat VI with GTR-4 and PEMS
	CO_2							1st Phase			2nd Phase					
	Limits	?	Euro IV, V or prior								?	Euro VI				

Emission Legislation – Heavy Duty Engines

Application:	Country:	Main Topics:

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

Euro VI since 2013:

- Particle Number (PN) limit established in addition to the Particulate Mass (PM) limit for Diesel engines.
- GTR-4 (Global Test Procedure) from UN-ECE.
- WHSC (World Harmonized Stationary Cycle) - Hot test
- WHTC (World Harmonized Transient Cycle) - 2 Tests one cold and one hot
- “Real Driving Emissions” limits by:
  - Random 15 mode stationary “Off Cycle Emissions” (OCE) test
    - app. 1700m and temperature up to 38°C (depending on altitude)
  - “In-Service” on-road tests in vehicle with PEMS (Portable Emission Measurement Systems)
    - CO2, CO, NOx, THC, PM (PN in discussion for EU)
    - Mix of urban (0-50 km/h), rural (50-75 km/h) and motorway (> 75 km/h) conditions
    - Temperature and Altitude as defines for off cycle emission requirements
    - Limits are based on the laboratory limits multiplied by 1.5 (CF)
    - Result calculation by “Work based window”

Emission Legislation – Heavy Duty Engines

Application:	Country:	Main Topics:

USA (EPA and CARB):

- All testing has to be done based on the technical regulation CFR-1065, since 2010.
- CFR-1065 is quite different to the old regulations CFR-86. CFR-1065 requires changes in all the complete measurement chain (analyzers, dilution systems, calculations, diagnostic checks, calibration, …), …) and cross interferences

USA (CARB):

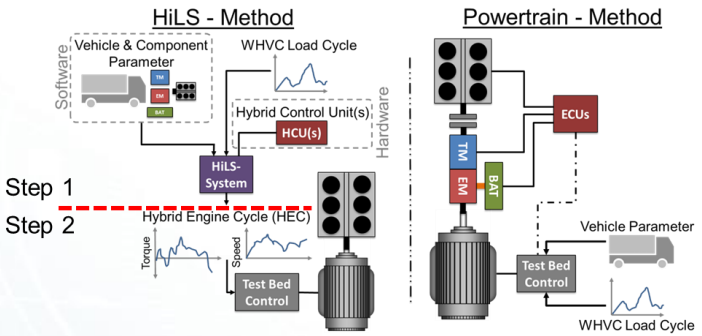
- CARB is proposing an “optional” lower NOx Limit for California. The currently valid 2010 NOX emission standard for heavy-duty engines of 0.20 g/bhp-hr, should be further reduced by a factor of 10.

CFR-1065:

- All measurement methods (Raw measurement, Partial flow dilution and Full flow dilution) are accepted for gaseous emissions and Partial flow dilution and Full flow dilution (CVS) is accepted for PM.
- A lot of new and challenging requirements, like for Analyzer, calibration and check procedures:
  - Continuous measuring analyzers must not have an analog gain switch.
  - Very challenging CLD Quench check specifications.
  - Accuracy, drift and linearity checks based on the emission standard and not anymore on analyzer range specifications.
- All calculation formulas are new and all are based on Mol

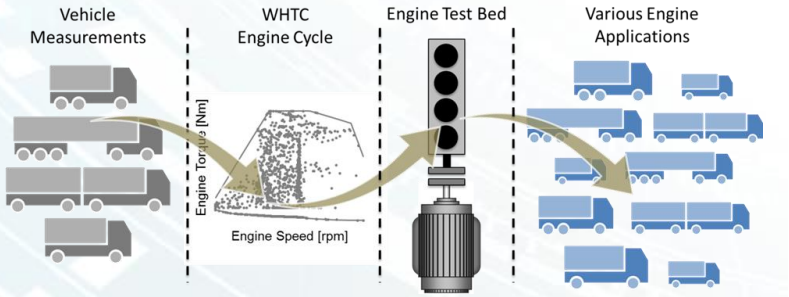
HEAVY-DUTY HYBRID, CO2 AND FC TESTING

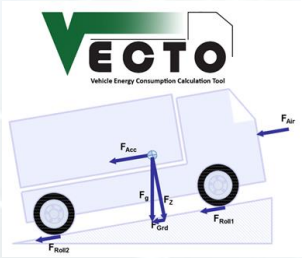
Hybrid Heavy Duty test procedure – from engine to powertrain



- For hybrid powertrains the total powertrain, energy storage and powertrain control units must considered.
- In order to avoid testing on a chassis dynamometer, a HILS (Hardware-in-the-loop simulation) was developed in Japan. In the WHVC cycle, the influence of the hybrid components on the engine operation is tested. 2 Variants exists:
  1. By HILS an engine test cycle is generated and tested on an engine testbed.
  2. The whole hybrid powertrain is tested on a powertrain testbed

CO2 and Fuel consumption labeling – from engine to vehicle





- Contrary to exhaust emissions, fuel consumption and CO2 emissions are not part of the GRPE mandate. Therefore, regional regulations are under development.
- EU: develops a vehicle based procedure, based on transport work and a simulation tool VECTO (TU-Graz) with 5 different test cycles representative for different vehicle categories. Implementation planed for 2018 for Trucks and 2019 Buses
- USA: Green House Gas rule developed by EPA and NHTSA. There are separate limits values for engine and vehicle. CO2 and FC are calculated with a simulation tool GEM.
- Japan: since 2015 fuel economy limits are based on a simulation approach. FC is calculated from engine testbed data and vehicle class generic vehicle parameters, which are base on JE05 and a motorway cycle.
- China: regulates on base of a modified WHVC to be run on a chassis dyno.

- Introduction
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  - Heavy Duty
  - Non-Road
- Evaporative Emissions
- CO2 emission reduction
- Future Mobility

Emission Legislation – Non-Road Engines

Country	Topic	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Notes
	Limits	III-B	Stage - IV					Stage - V								
	RDE		**NTE**					**Off-Cycle + in-service monitoring (PEMS)**								
	CO2					**CO_2** Monitoring & Declaration										
	Tech. Reg.	**ISO**	**GTR-11** (NRSC + NRTC test cycles)													
	Limits	Tier-4														
	RDE									**PEMS in Discussion (NRIUT)**						Currently no progress
	CO2	**GHG Regulation and CO2** Monitoring & Declaration														
	Tech. Reg.	**CFR-1065**														
	Limits	China II				China III				**China IV**						2020 + DPF/PN, PEMS with CF NOx
	Limits	Stage - III				Stage - IV									Stage V	Discussions on post Stage IV regulation
	Limits	Tier - 3				Tier - 4										
	Limits	CEV/TREM III								BS IV			Stage V			Stage V + ISC with PEMS, CF tbd
	Limits	?	Stage IIIA / Tier-3 or prior										?	Stage-IV / Tier - 4		

EU Stage V

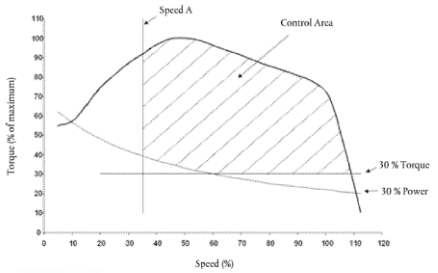
Application:

Country:

REGULATION (EU) 2016/1628 (replacing Directive 97/68/EC, amended by 2012/46/EC)

- All power categories are regulated for the first time.
- Dual-Fuel (Gas) requirements defined
- Engine Categories:
  - NRE CI and SI with constant and variable speed, all power ratings
  - NRG Mobile generating sets with reference power > 560 kW (< 560 kW □ NRE)
  - NRSh Handheld SI engines < 19 kW
  - NRS Non-Handheld SI engines < 19 kW
  - IWP propulsion inland waterway vessels engines >= 19 kW
  - IWA auxiliary inland waterway vessels engines >= 19 kW
  - RLR Engines for railcar propulsion
  - RLL Engines for locomotive propulsion
  - SMB Snow mobile SI engines (non SI □ NRE)
  - ATS SI engines for All Tertain and side-by-side vehicles (non SI □ NRE)
- For agricultural tractors the Delegated Regulation (EU) 2015/96 amending Regulation (EU) 167/2013 applies. (EU) 2015/96 needs to be adjusted to account for the provisions of EU Stage V Regulation
- Compliance with the limits must be demonstrated over the useful lifetime of the engine (as of IIIA), from Stage V, variable speed and constant speed engines are treated equally.
- CO2 to be measured and reported, indication for CO2 limitation in future

EU Stage V



AVL M.O.V.E GAS

NTE (Not to Exceed) on test beds

- For electronically controlled engines of categories NRE, NRG, IWP, IWA, and RLR.
- When an engine is tested … emissions sampled at any randomly selected point within NTE area … shall not exceed the applicable emission limit values … by a factor of 2.0.
- The technical service shall select random load and speed points within the control area for testing (NRSC C1 cycles up to three points; NRSC D2, E2 and G2 one point).

In service monitoring (ISM)

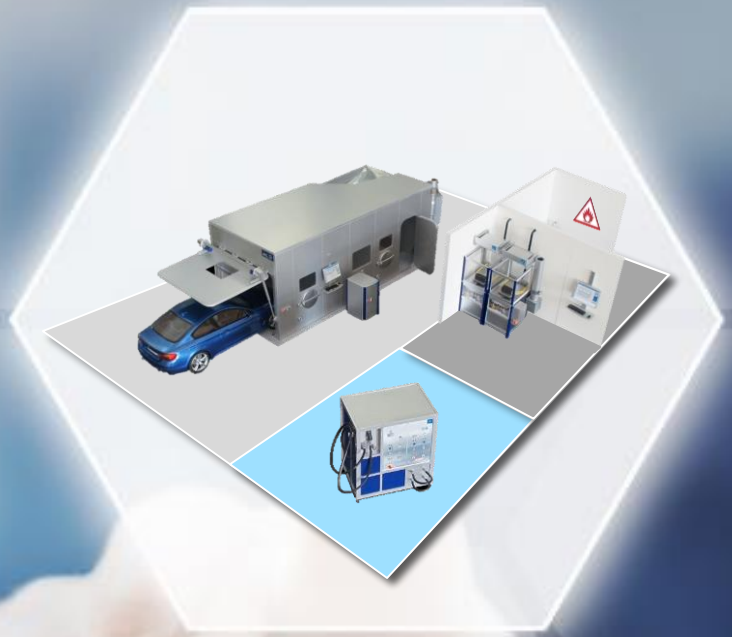
- PEMS (Portable Emission Measurement System)
- Gaseous emissions only (CO, HC, NOx, CO2), PM/PN is not in the scope
- Monitoring and reporting, but no limits.

NOx control diagnostics (NCD)

- NOx control and diagnostics (NCD)
  - Low reagent level, Reagent quality monitoring, Reagent dosing activity, Failures that might be attributed to tampering, impeded EGR valve, Removal or deactivation of any sensor that prevents the NCD from diagnosing failures
- Particulate control diagnostics (PCD)
  - Removal of the DPF or substrate, failures attributed to tampering, electrical failures, removal or deactivation of any sensor or actuator.
- Operator warning / inducement system

ISO 8178 - Parts

Part	Title and Topic	Notes
1	Test bed measurement systems for gaseous and particulate emissions	3rd edition 2017: with up-dates and alignment with CFR-1065, Formulas were moved to Part-4 and transient testing implemented from Part-11
2	Measurement of gaseous and particulate exhaust emission at site	only when Part-1 is not possible and agreed by involved parties. 2nd edition published in 2008. Will be up-dated with PEMS testing
3	Definitions and methods of measurement of exhaust gas smoke under steady-state conditions	Edition 1994 with Opacity and FSN filter smoke number. Revision started 2017: moving Opacity to Part-9, maybe adding BC
4	Test cycles for different engine applications	3rd edition 2017: Implementations of formulas from Part-1 and transient test cycle from Part-11
5	Test fuels	3rd edition 2015, 2017 revision started
6	Report of measuring results and tests	2013 revision started, draft approved in 2017.
7	Engine family determination	Engine variations with similar characteristics and design represented by one engine of the "engine family". 2nd edition 2015.
8	Engine group Determination	"Engine group" are engines of the same type, but modified when put into service. Still must comply with emission limits. 2nd edition 2015.
9	Text cycles and test procedures for test bed measurement of exhaust gas smoke emissions from compression ignition engines operating under transient conditions	2nd edition 2012, 2017 revision started: Implementation of opacity measurement from Part-3 relevant parts from Part-10. (done by AVL)
10	Test Cycles and test procedures for field measurement of exhaust gas smoke emissions from compression ignition engines operating under transient conditions	1st edition 2002, 2017 revision started: Smoke measurement moved to Part-9.
11	Test-bed measurement of gaseous and particulate exhaust emissions from engines used in non-road mobile machinery under transient test conditions	"Withdrawn" (Edition from 2006). Content implemented in other parts, like transient cycle and formulas in Part-4, measurement in Part-1



Introduction

Tail pipe emission legislations:

- Light Duty
- Heavy Duty
- Non-Road

Evaporative Emissions

CO2 emission reduction

Future Mobility

EVAP: Evaporative Emission

EVAP measuring evaporative emissions (mainly from fuel) form the complete vehicle, but only gasoline vehicles

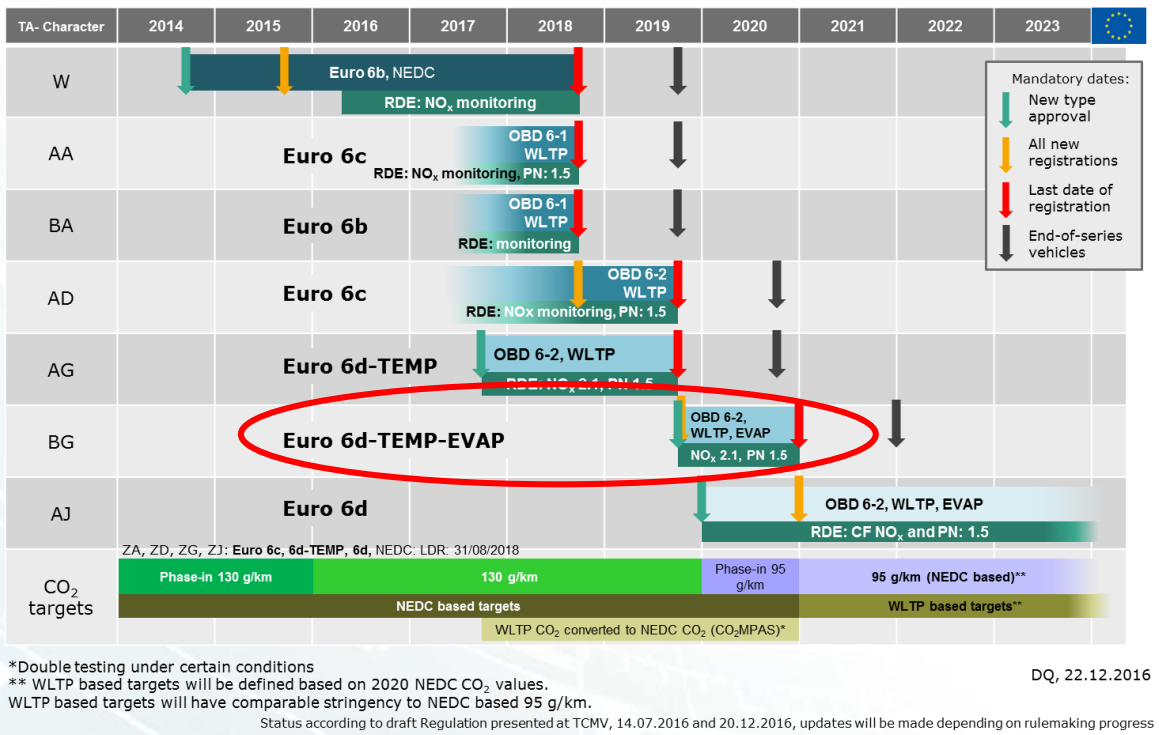
+ Point Source running a tailpipe emission cycle and measuring EVAP from selected points
+ Running Loss running an tailpipe emission cycle inside a SHED and measuring EVAP
+ Permeation test measuring the permeation of fuel system components

EVAP outlook

Current: little changes in worldwide EVAP legislation, therefore installed base 10 to 15 years old

Mid Term (2019): WLTP/EVAP EU, Japan and China will up-date its legislation, with modified or new test procedures

EU Legislation

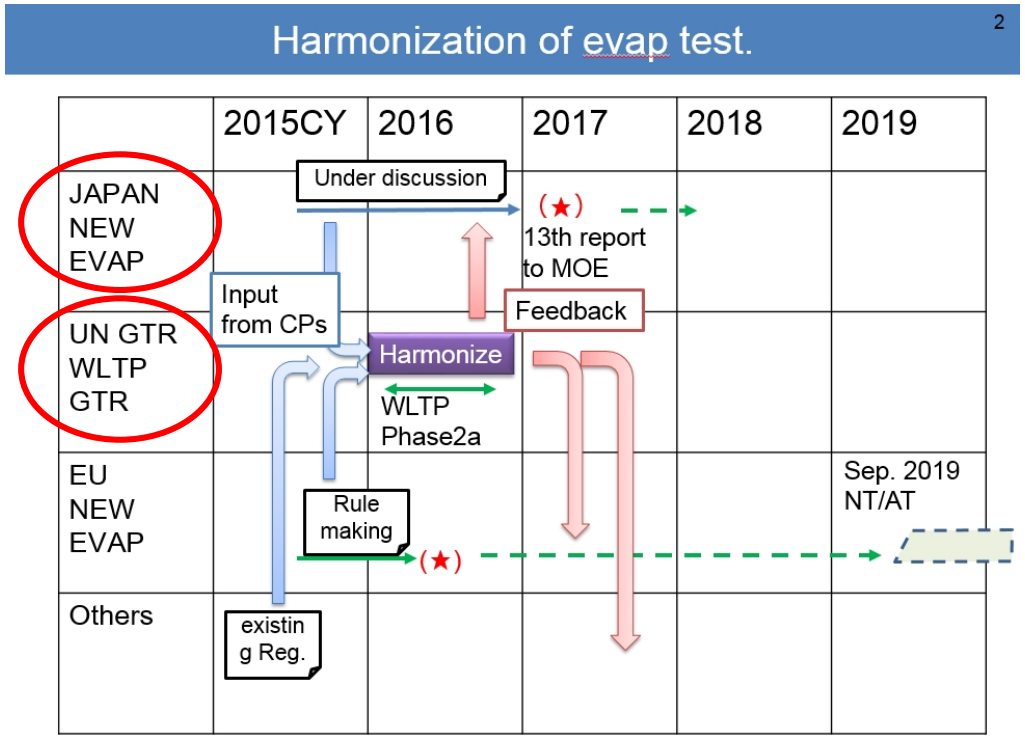


*Double testing under certain conditions
** WLTP based targets will be defined based on 2020 NEDC CO_2 values.
WLTP based targets will have comparable stringency to NEDC based 95 g/km.

DQ, 22.12.2016

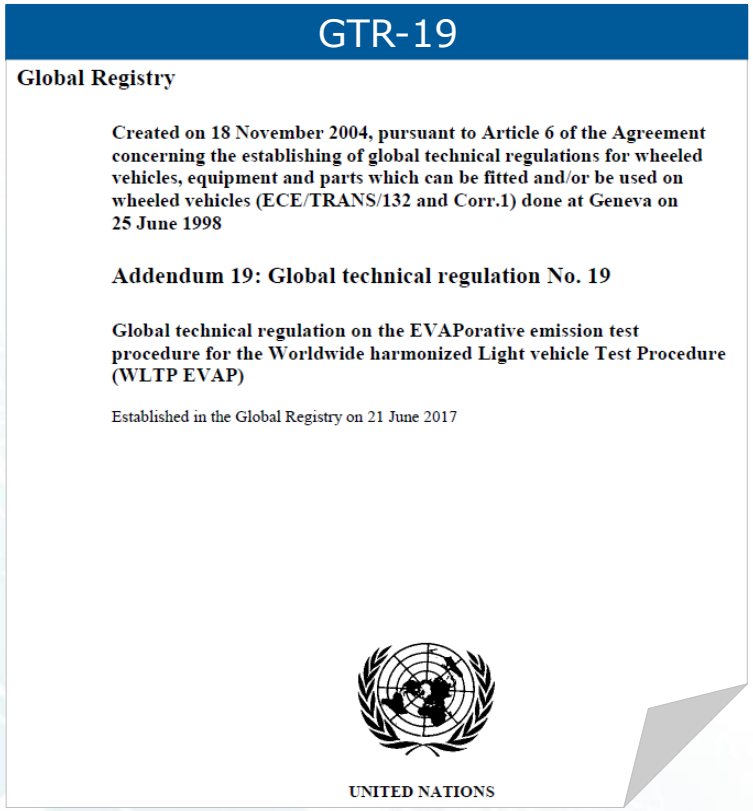
Status according to draft Regulation presented at TCMV, 14.07.2016 and 20.12.2016, updates will be made depending on rulemaking progress

Road map WLTP, GTR, EU and Japan



Long Term (2022): a new worldwide (except USA) Global Technical Regulation (GTR) will be established

UNR: GTR-19


GTR-19

Global Registry

Created on 18 November 2004, pursuant to Article 6 of the Agreement concerning the establishing of global technical regulations for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles (ECE/TRANS/132 and Corr.1) done at Geneva on 25 June 1998

Addendum 19: Global technical regulation No. 19

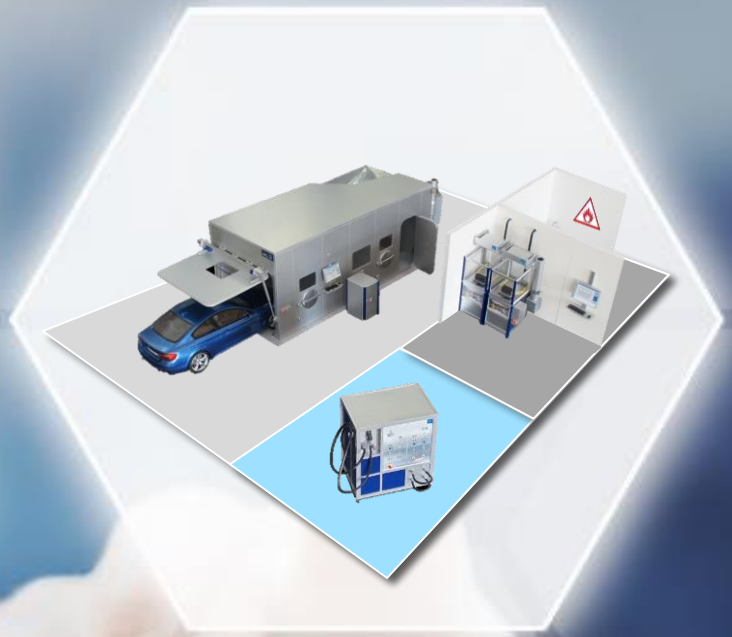
Global technical regulation on the EVAPorative emission test procedure for the Worldwide harmonized Light vehicle Test Procedure (WLTP EVAP)

Established in the Global Registry on 21 June 2017

UNITED NATIONS

Main GTR-19 topics:

- Effective control of evaporative emissions in real life and improved durability
  - replacing UNR-83 (NEDC) with WLTP test procedures
  - **Fuel tank aging**
  - **Carbon Canister fuel aging**
  - **Sealed fuel tank systems (mainly for plug-in hybrids)**
- not in the scope currently
  - no running losses test (running losses SHED nor Point Source)
  - no refueling emission tests



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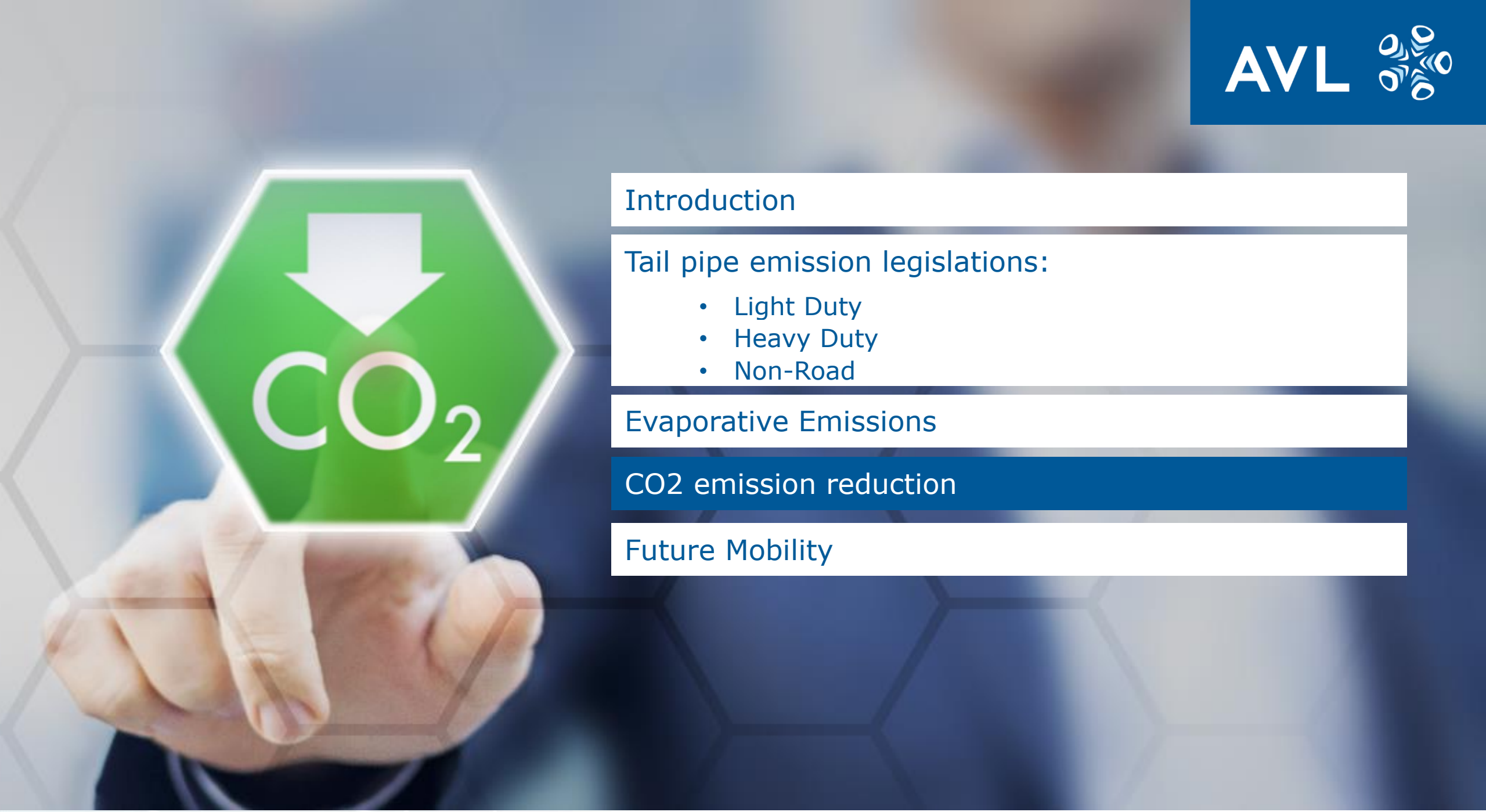
CO2 emission reduction

Future Mobility



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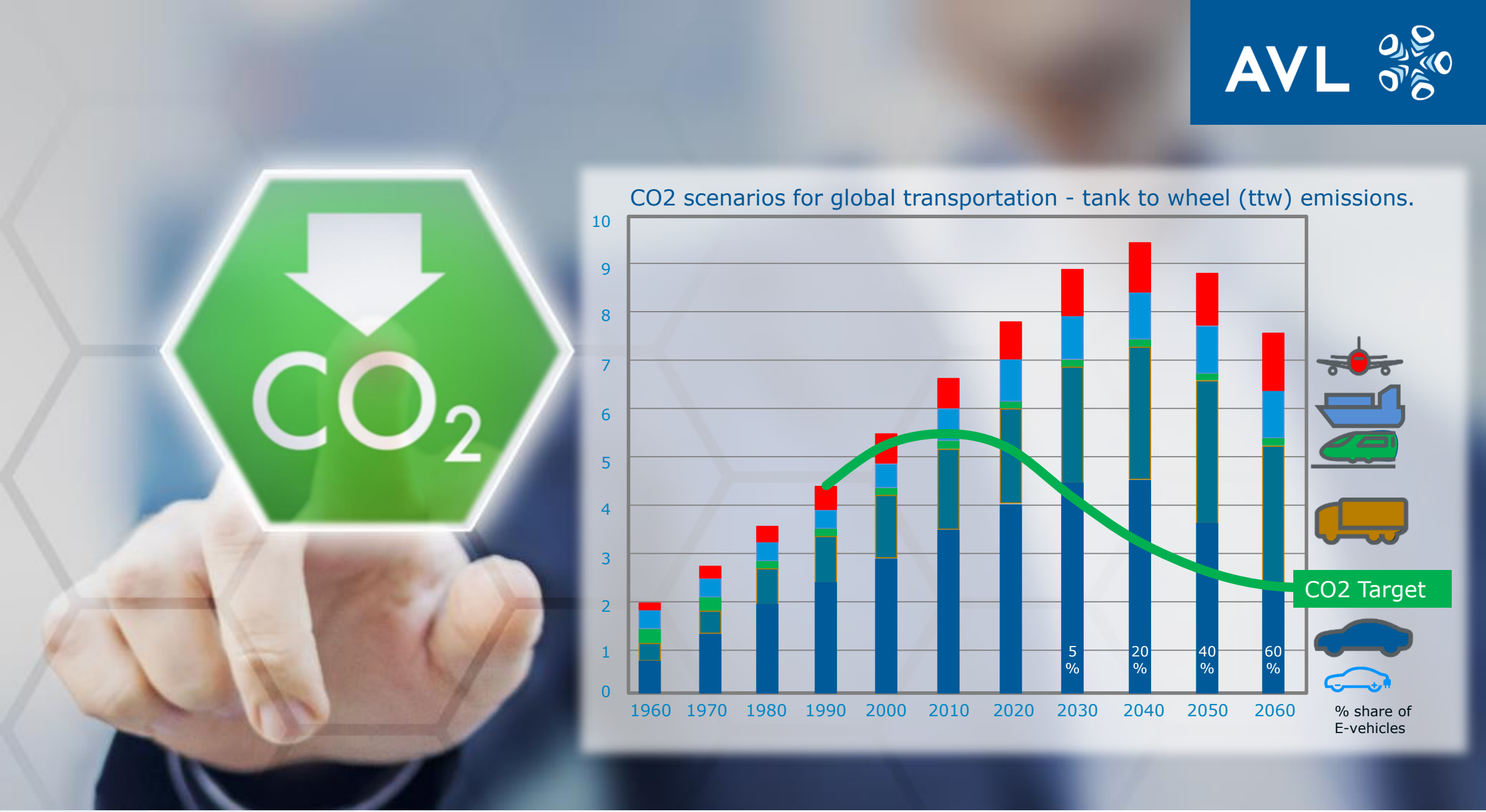
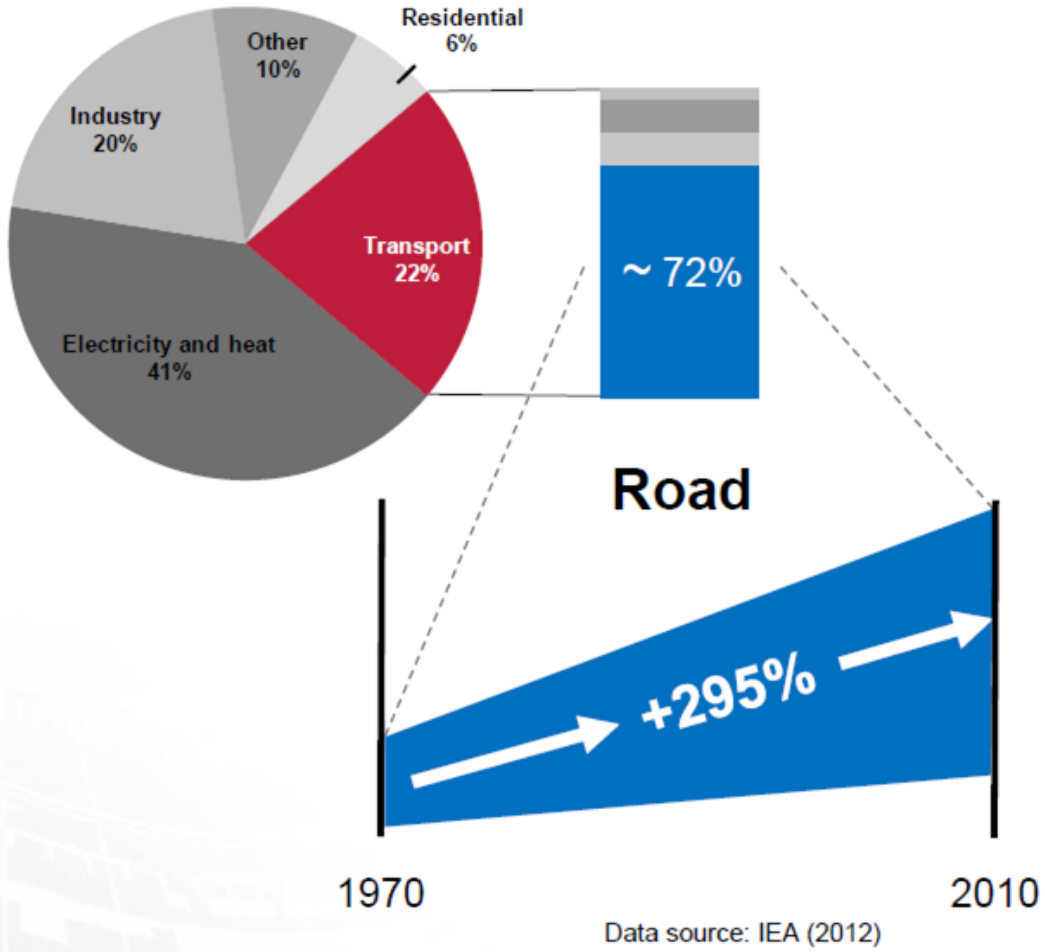
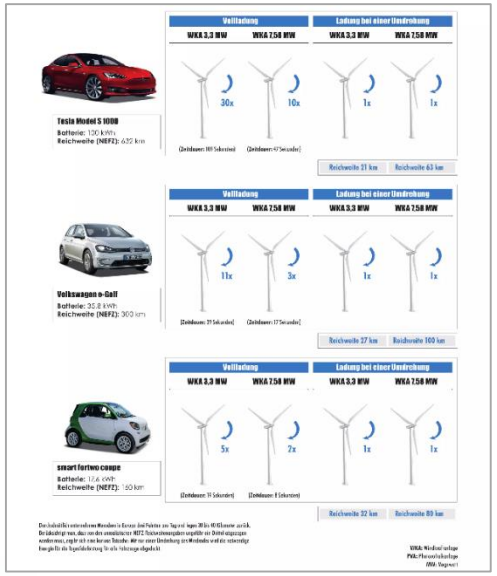

CO2 scenarios for global transportation - tank to wheel (ttw) emissions.
10
9
8
7
6
5
4
3
2
1
0
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
5 %
20 %
40 %
60 %
CO2 Target
% share of E-vehicles

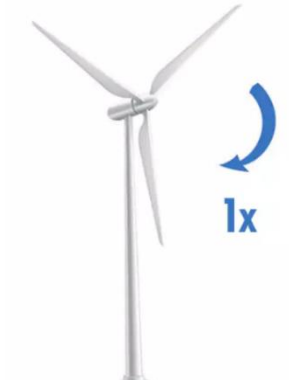
CO2 Emissions



Source: Life Cycle Environmental Impacts of EVs and the Significance of the Battery System
Felipe Cerdas, MSc., Prof. Dr-Ing. Ch. Herrmann, Technische Universität Braunschweig @ AVL Exhaust and Particulate Forum, Ludwigsburg, 2018

eMobility





Only 1 turn of the propeller of a 8 MW wind propeller (200 m height) will drive the car:

63 km

Tesla Model S 100D
Battery 100 kWh
Electr. Range 630 km (NEDC)

80 km

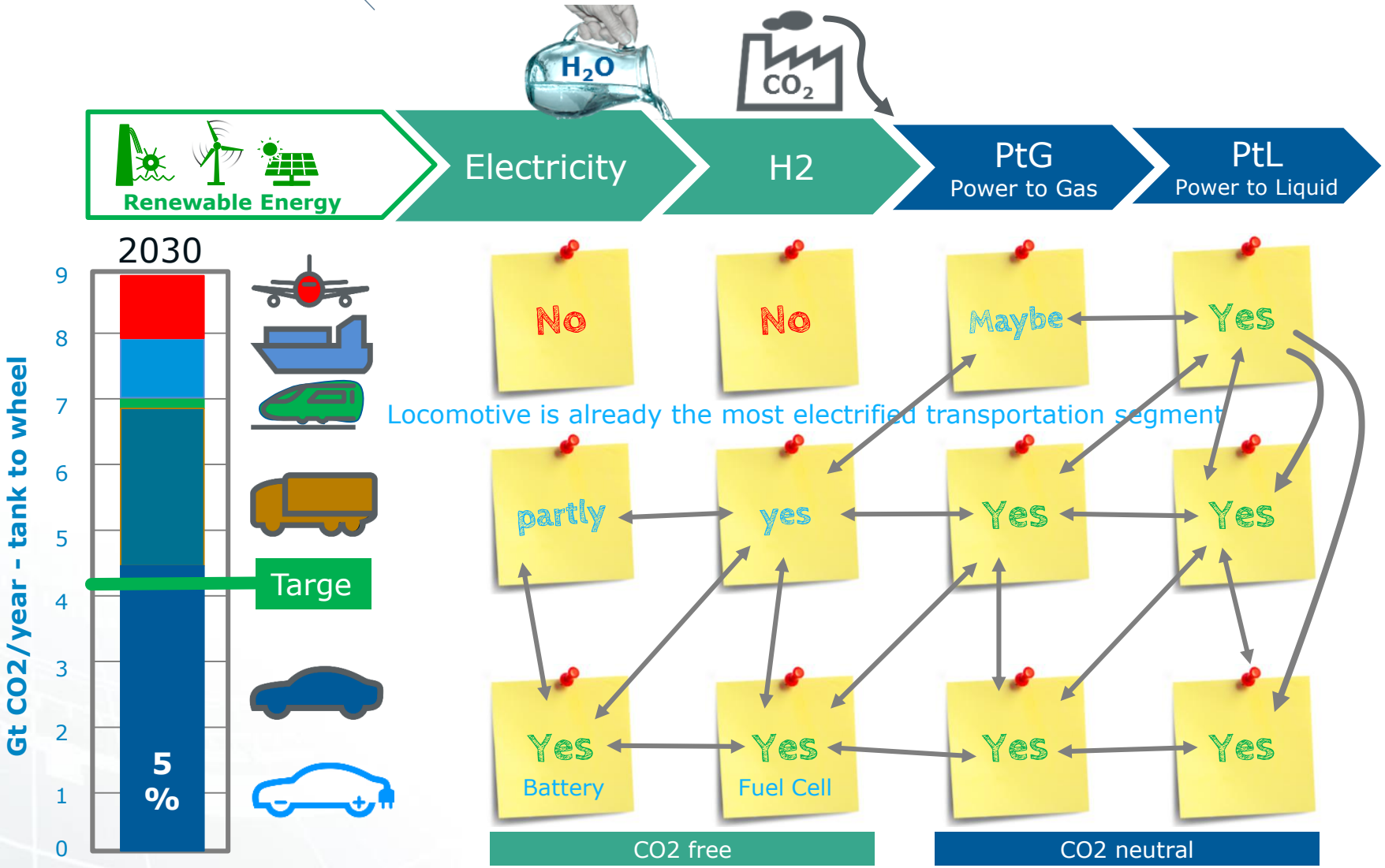
VW e-Golf
Battery 36 kWh
Electr. Range 300 km (NEDC)

100 km

smartfortwo coupe
Battery 18 kWh
Electr. Range 160 km (NEDC)

Source: Elektroautomobil - Das Magazin für Elektromobilität, 2018

CO2 Emissions – one possible scenario



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CO2 emission reduction

Future Mobility

The future comes in how many years?

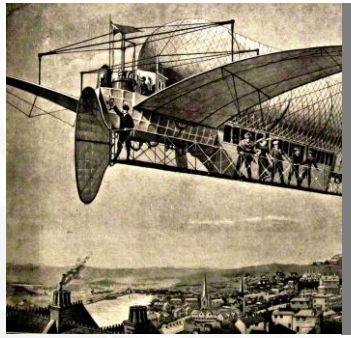
Electric car

120 years

Autonomous driving

65 years

Flying car



150+ years

Successfully predicting the future

7 years

23 years

20 years

15 years


AVL
www.avl.com
Our Customer Emission
is our Mission

CO2: electric vehicle life-cycle emission

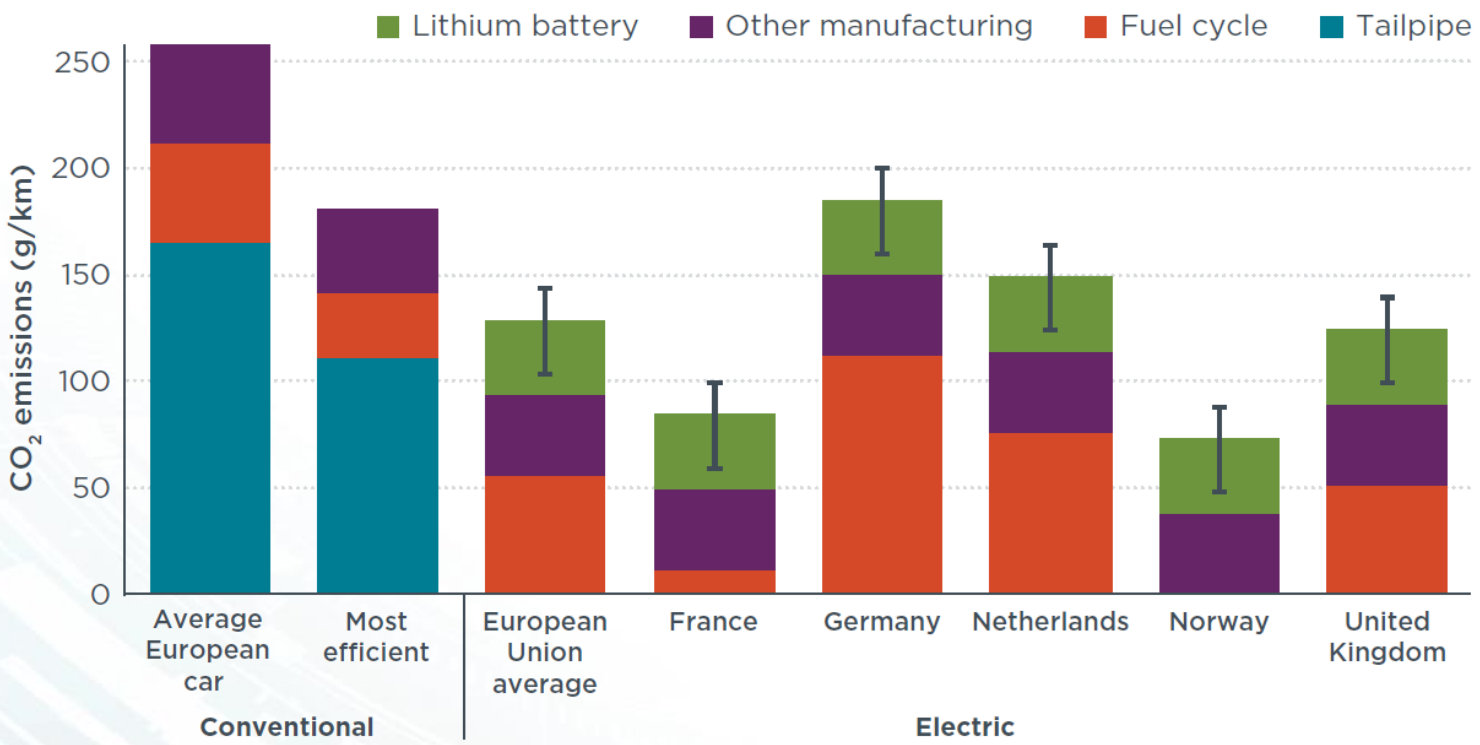


Figure 1. Life-cycle emissions (over 150,000 km) of electric and conventional vehicles in Europe in 2015.

Life-cycle impact of a vehicle:

- Life-cycle impact of a vehicle is the sum of the emissions impacts from manufacturing, energy cycle, and use.
- Overall, electric vehicles typically have much lower life-cycle greenhouse gas emissions than a typical car in Europe, even when assuming relatively high battery manufacturing emissions.
- An average electric vehicle in Europe produces 50% less life-cycle greenhouse gases over the first 150,000 kilometers of driving, although the relative benefit varies from 28% to 72%, depending on local electricity production.
- An electric car's higher manufacturing emissions would be paid back in 2 years of driving with European average grid electricity compared to a typical vehicle. This emissions recovery period is no more than 3 years even in countries with relatively higher-carbon electricity such as in Germany.

Source: Effects of battery manufacturing on electric vehicle life-cycle greenhouse gas emissions ICCT, February 2018