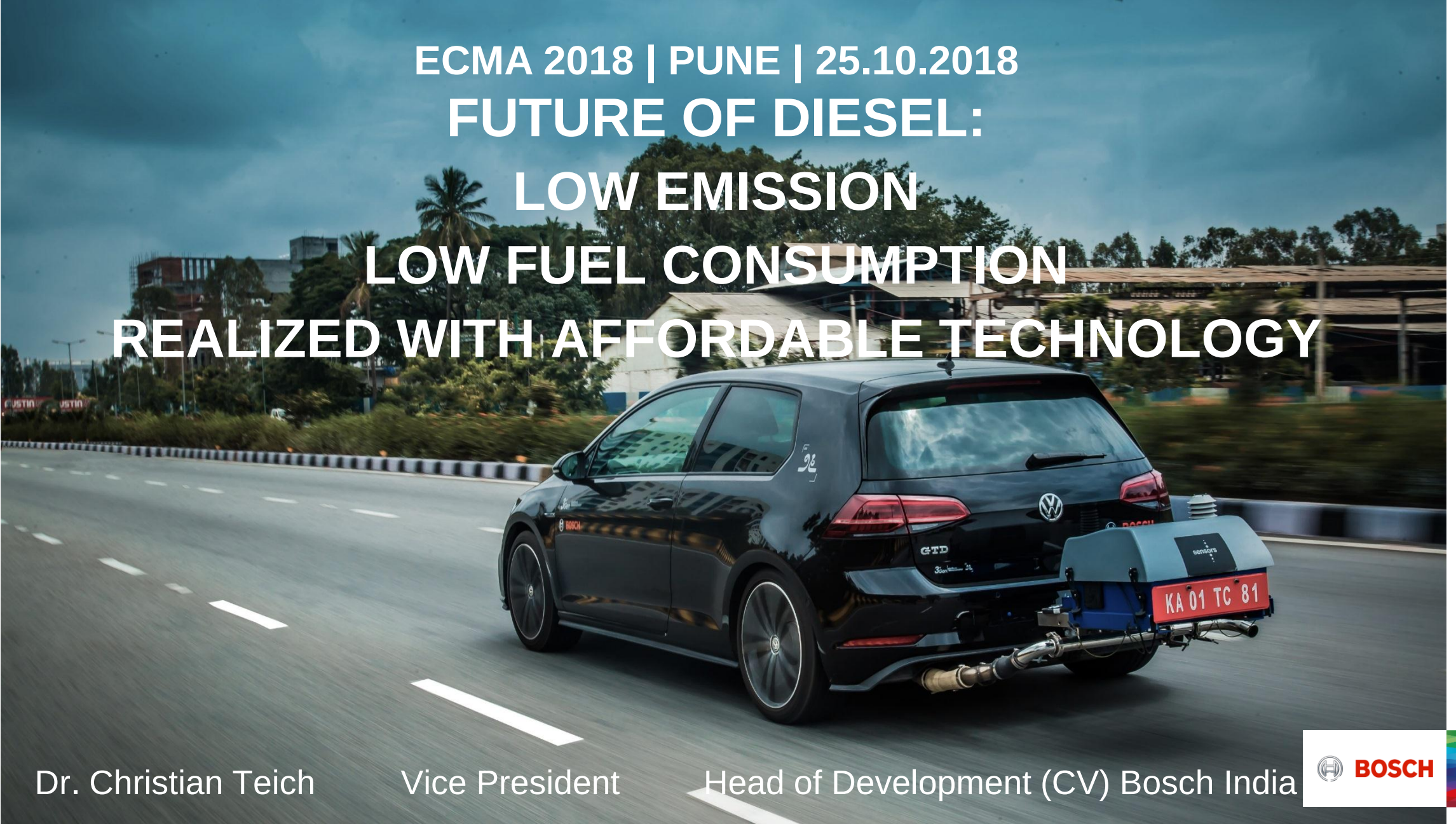
ECMA 2018 | PUNE | 25.10.2018

FUTURE OF DIESEL:
LOW EMISSION
LOW FUEL CONSUMPTION
REALIZED WITH AFFORDABLE TECHNOLOGY



Dr. Christian Teich Vice President Head of Development (CV) Bosch India

BOSCH

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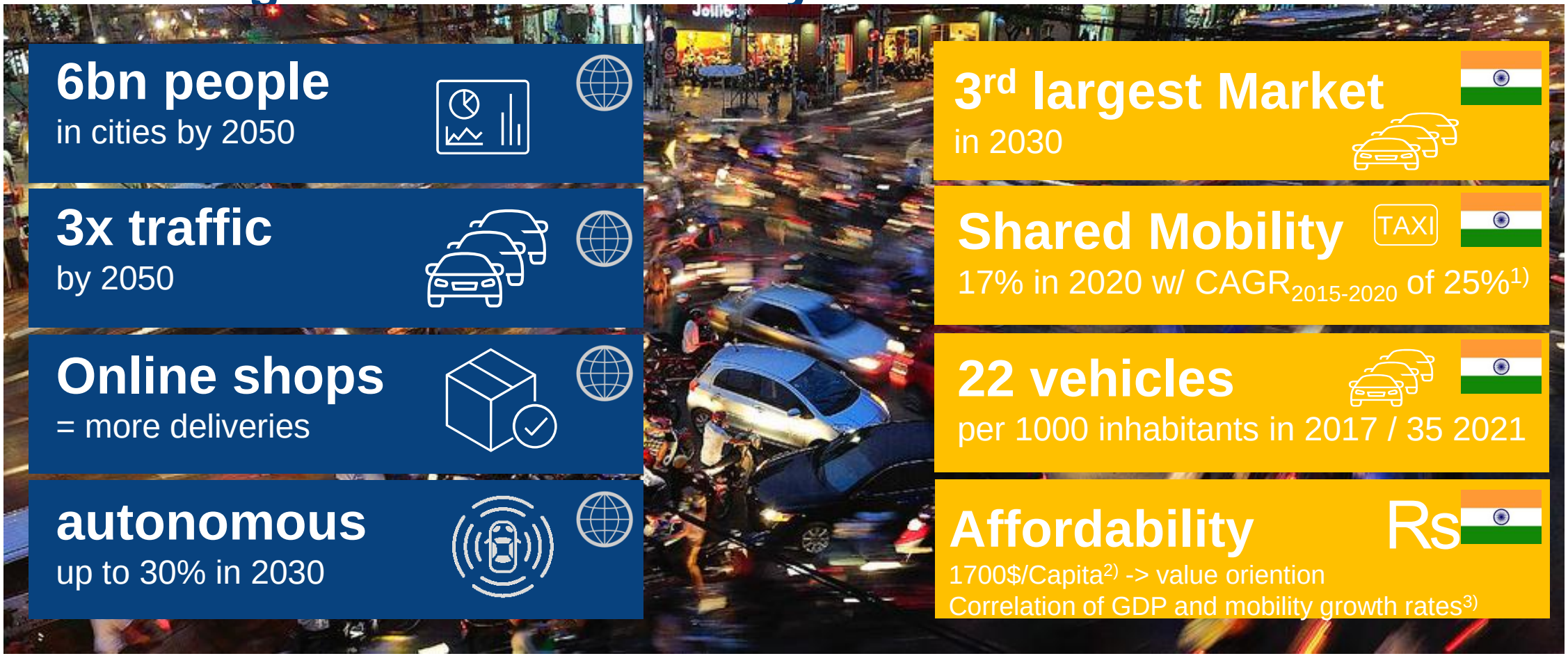
Increasing demand for “Mobility – re-defined”



6bn people
in cities by 2050

3x traffic
by 2050

Online shops
= more deliveries

autonomous
up to 30% in 2030

3rd largest Market
in 2030

Shared Mobility
17% in 2020 w/ $CAGR_{2015-2020}$ of 25%[1)]

22 vehicles
per 1000 inhabitants in 2017 / 35 2021

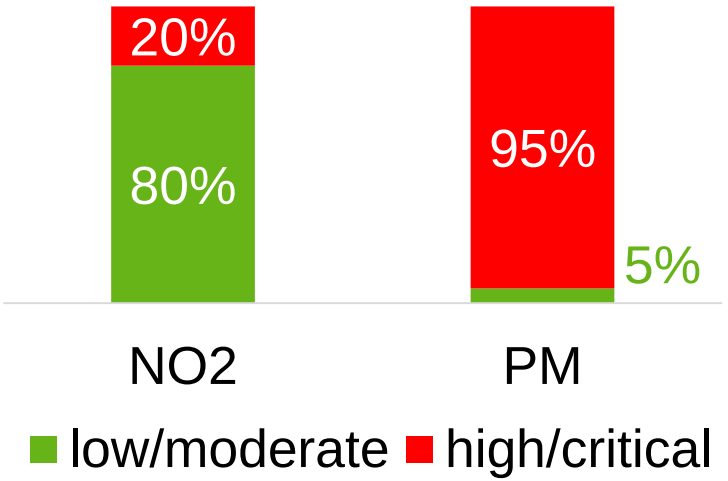
Affordability
1700$/Capita[2)] -> value orientation
Correlation of GDP and mobility growth rates[3)]

1) Forecast ICRA 2) World Bank 2016 3) Correlation of GDP growth 2009-2016 in India: CV: R^2=0.84 , PC,LCV: R^2=0. 3)Bosch internal Powertrain Scenarios 09/2017

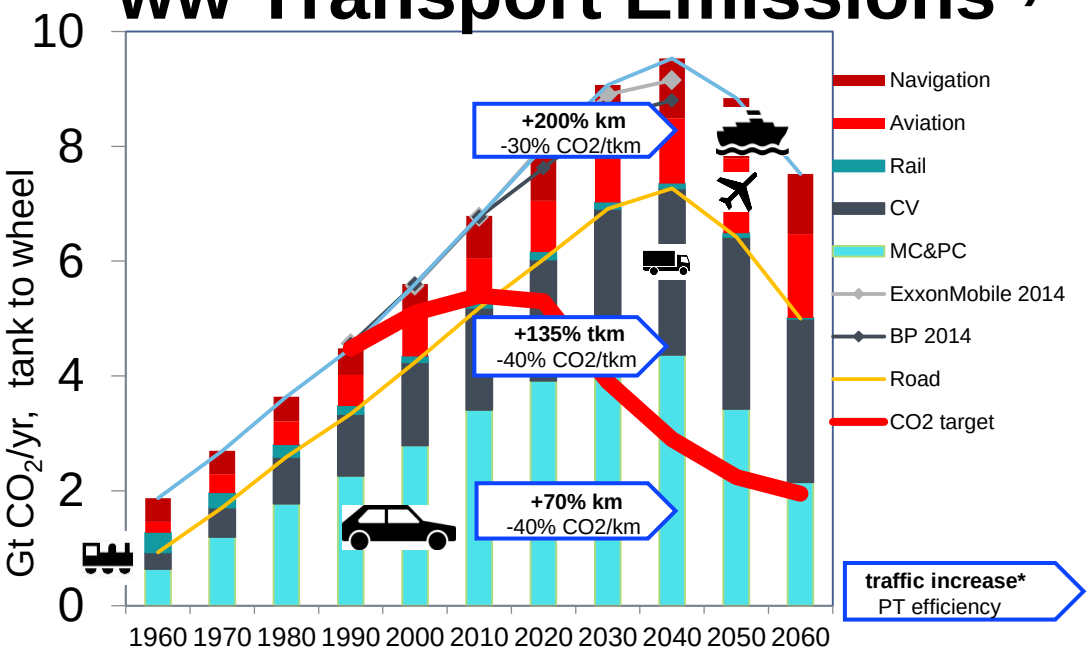
Immissions

Air Pollution

in 40 large Cities in India [1)]



ww Transport Emissions[2)]

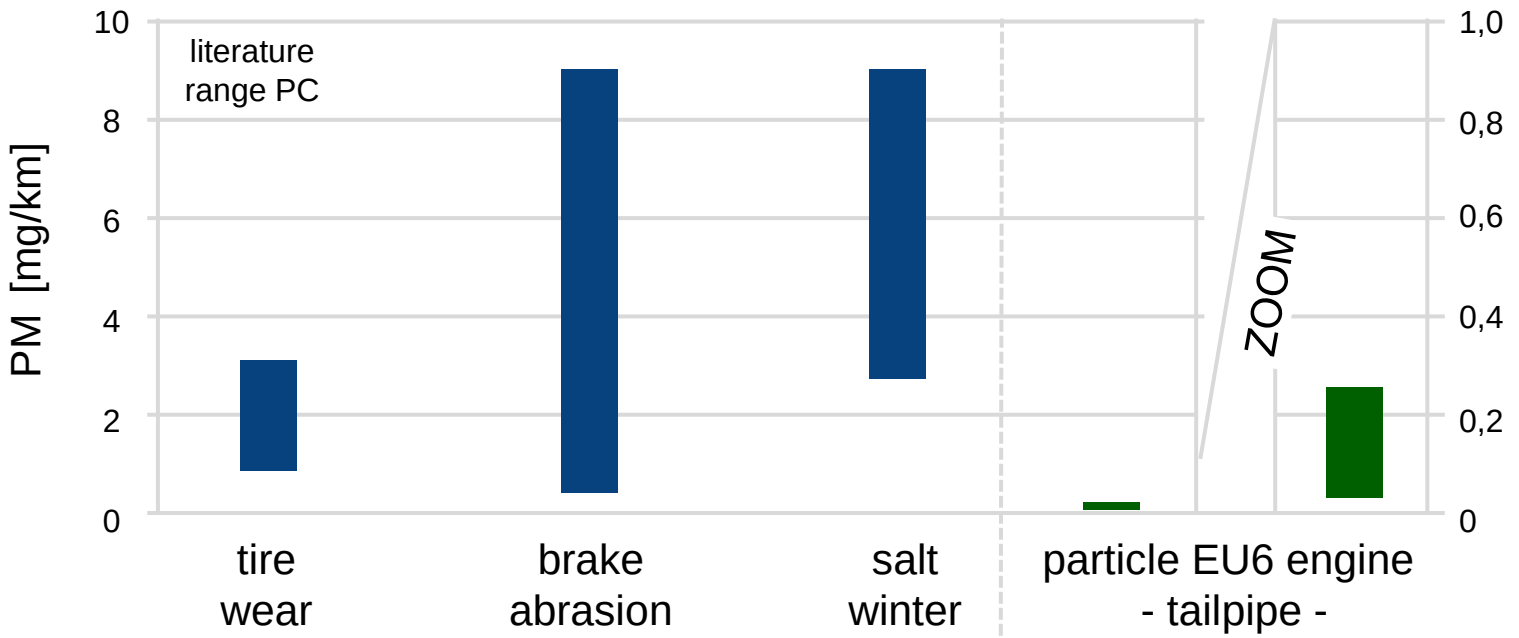


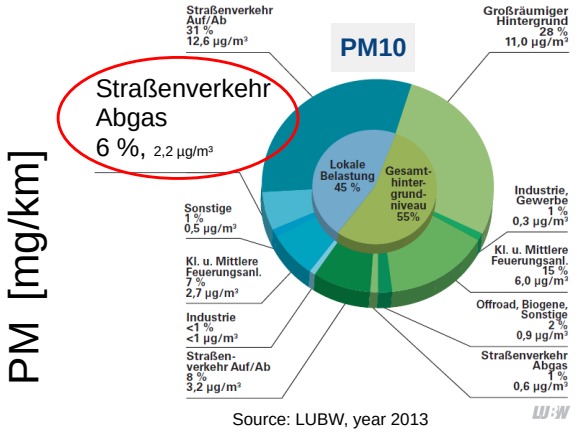
1) CPCB Annual Report 2015/2016 Air Quality for 40 cities >1 Mio inhabitants in 2015. Immission valus in ug/m³ NO_2 : low (0-20), moderate (21-40), high (41-60), critical (>60), PM: low (0-30), moderate (31-60), high (61-90), critical (>90)

2) Source: Shell Mountains Scenarios 2013; *ExxonMobile 2014, BP 2014

Example: Air Quality Stuttgart: PM_{10}

Solved PM/PN emissions, but where are the particles coming from?





Source: LUBW, year 2013

Engine out PM emissions from traffic negligible compared to other sources

6% of 41 ug/m³

PM-Imissions was attributed to on-road mobility in 2013 in Stuttgart

With Introduction of DPF Tailpipe out PM emissions from traffic negligible compared to other sources.

Source:
Straßenverkehrsemissionen in Europa - Emissionsbetrachtung und Bewertung von Minderungsmaßnahmen, Ulrike Kugler, 2012
Ermittlung des Beitrages von Reifen-, Kupplunga- und Bremsabrieb an den PM10-Emissionen von Straßen, 2008

Air quality – RDE
Overview of Diesel Powertrain Applications

CO_2:
outstanding, further improvement possible

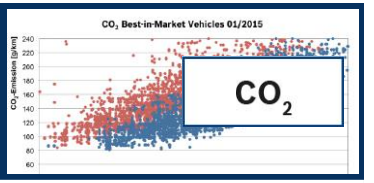
PN / PM:
negligible contribution for immissions

CO / HC:
on very low level

Potential

CO_2 emissions / fuel consumption

- Current Diesel engines with excellent fuel economy
- Further improvements – with and without electrification – possible

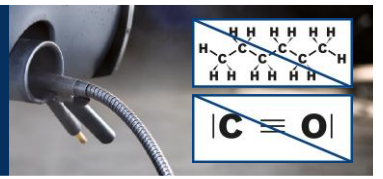


Particle emissions (PN / PM)

- With introduction of closed particle filter (≥ EU5) no longer an issue
- Typical filtration efficiency > 95 %

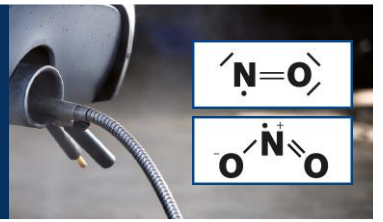
CO / HC emissions

- Due to lean combustion extremely low cold start emissions
- With introduction of oxidation catalyst no longer an issue



NO_x emissions

- RDE setup will reduce NO_x engine out emissions to fulfil air quality immission targets
- CO_2 benefit of Diesel RDE applications will remain
- Combination of engine-related measures and exhaust-gas aftertreatment mandatory

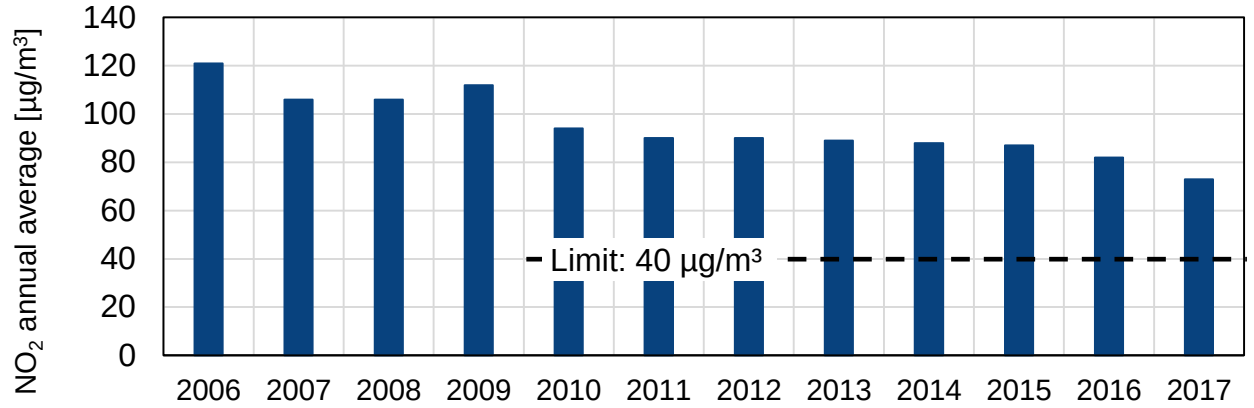


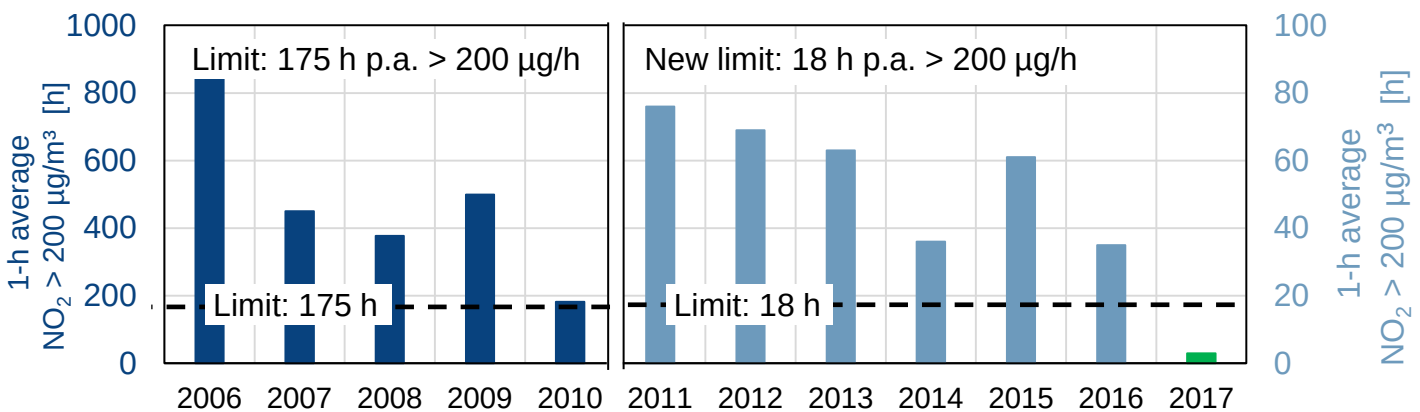
Target: Fulfilment of air quality immission targets with
no significant cost increase and w/o deterioration of general Diesel CO_2 advantages

BOSCH

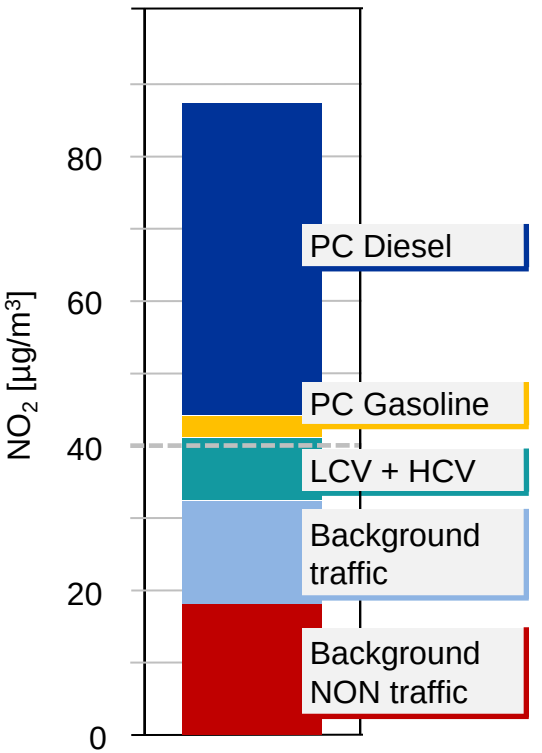
Bosch new Diesel technology

Trend of NO_2 values @Stuttgart “Am Neckartor”





Ambient air quality: NO_2 shares 2015



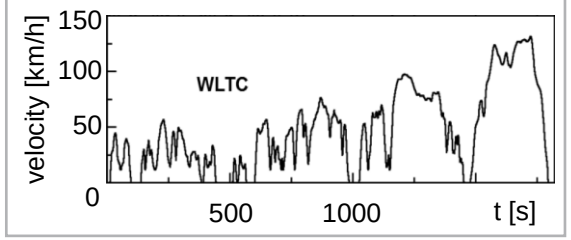
Data source: Stadt Stuttgart, LUBW and Umweltbundesamt

Despite progress, NO_2 immissions are still above legal limits. Diesel is a major contributor.

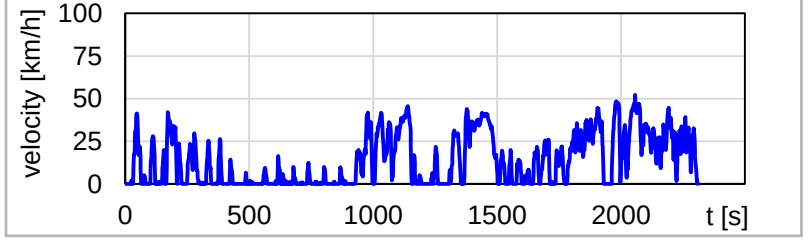
Bosch EU6-RDE Testing Conditions

Test Cases on Roller Dyno and Public Road

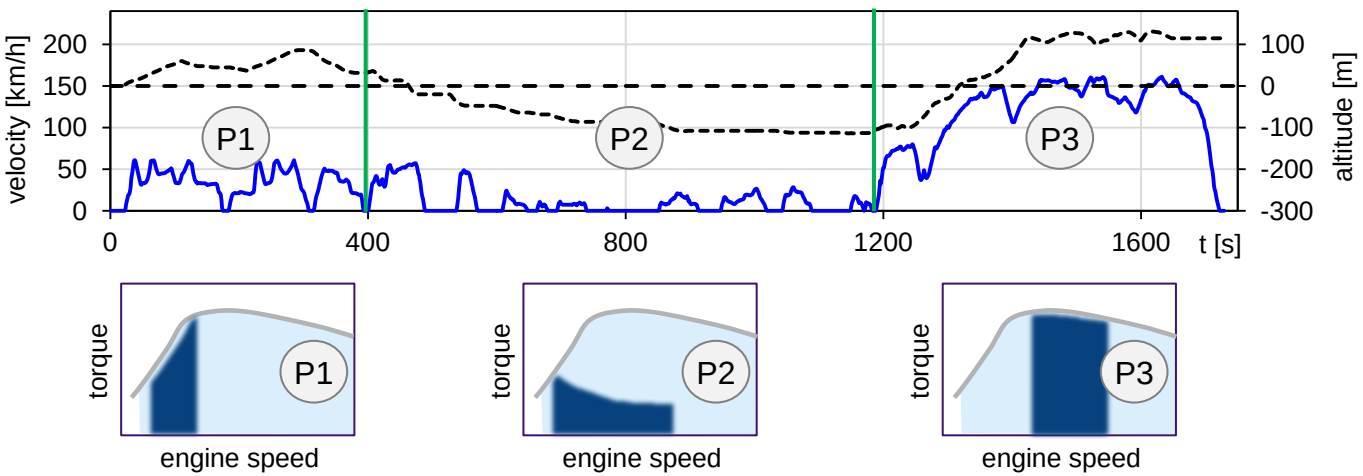
WLTC



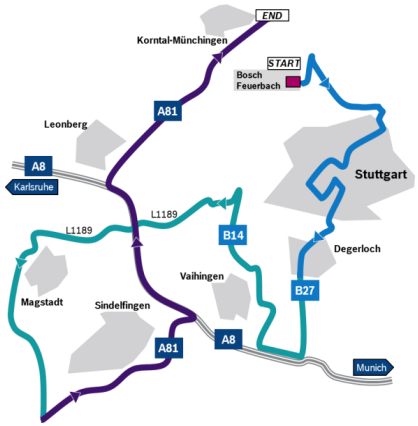
Transport for London



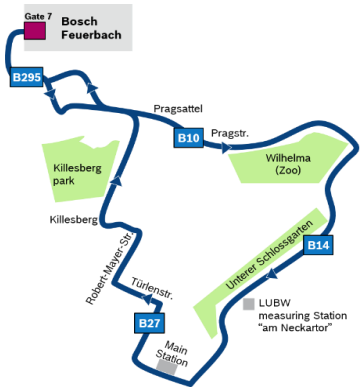
Challenge Cycle (Bosch internal)



Bosch Stuttgart track

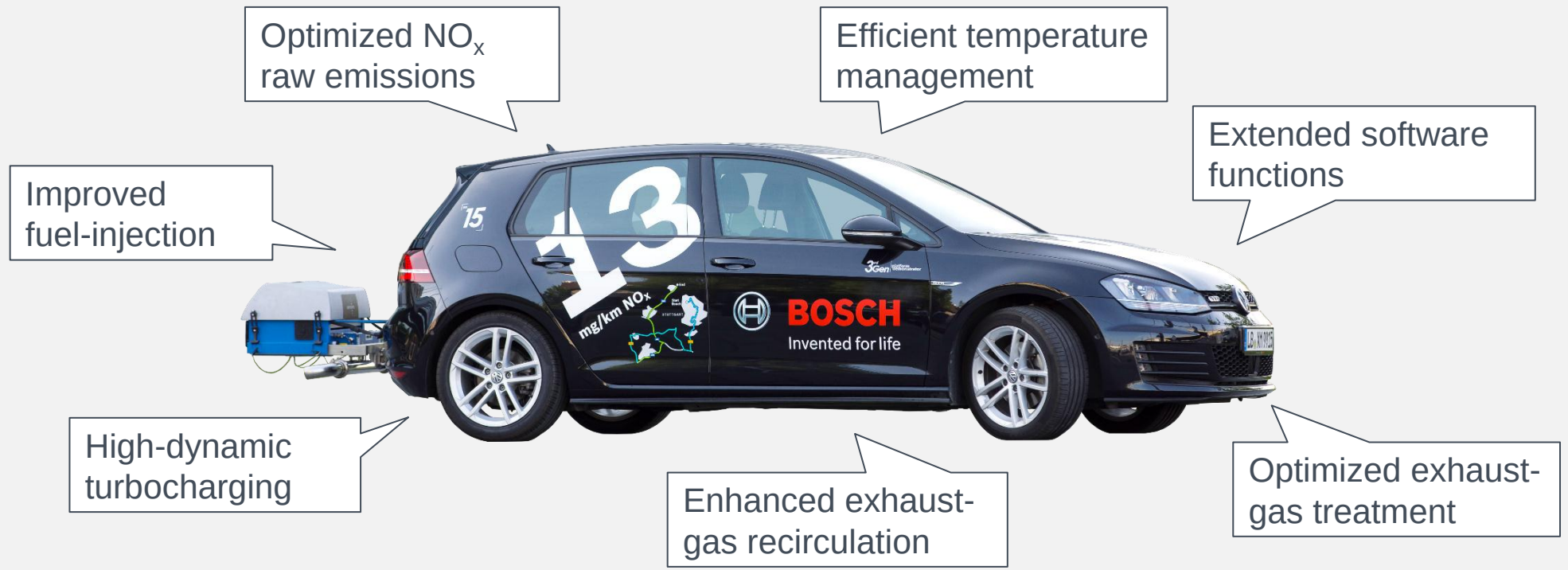


Bosch Stuttgart urban track



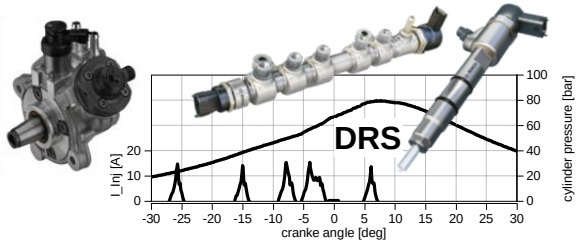
BOSCH

Bosch new Diesel technology
A combination of various measures



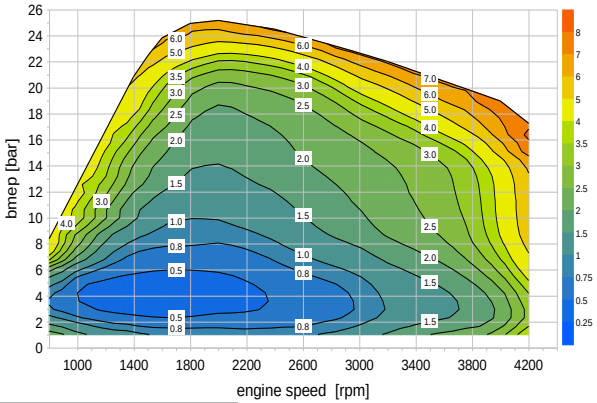
A customer-independent development: Existing technologies, substantially modified, reduce emissions.

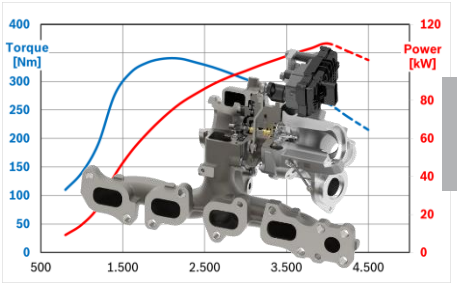
Bosch Test Vehicle / Demonstrator
Details: Combination of Measures



Fuel injection equipment

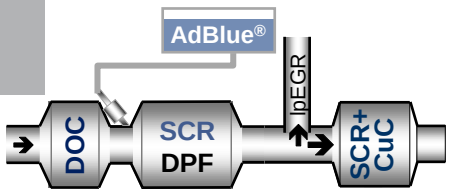
Minimized NO_x raw emission

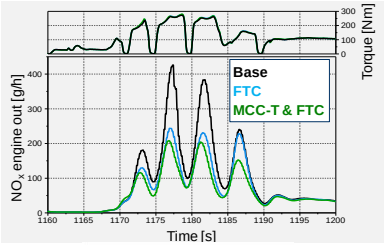




Improved turbocharging

Exhaust-gas treatment

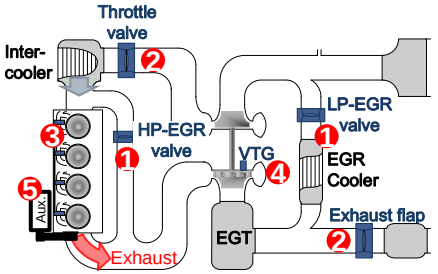




New software functions

Engine	1.7 l / 4 cyl.
Power	110 kW
Torque	340 Nm
Fuel injection equipment Pressure	CRS2 2200 bar
Exhaust gas recirculation	LP + HP-EGR
Charge air cooler	Water cooled

Temperature management



Optimization in a system approach

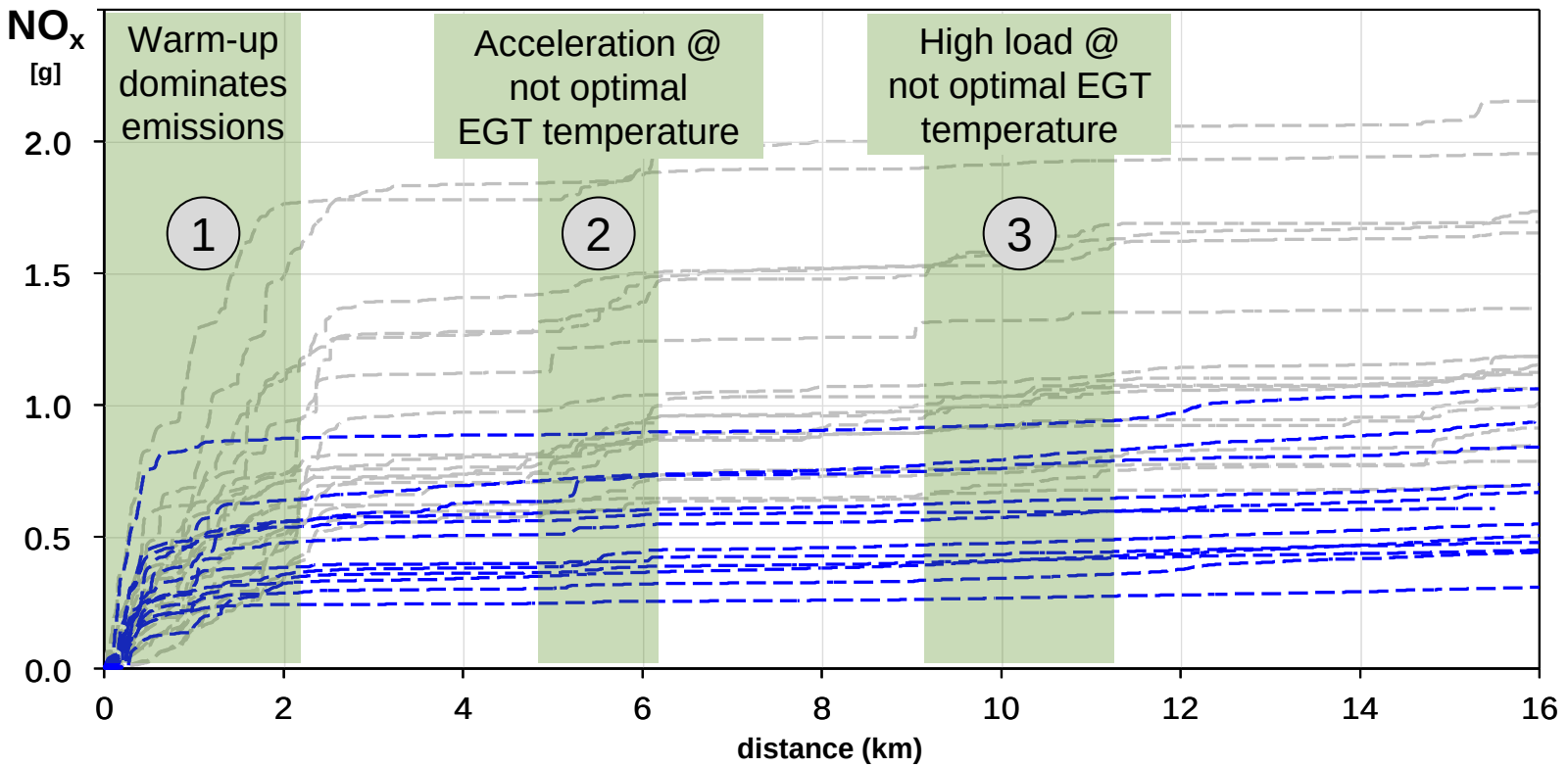
BOSCH

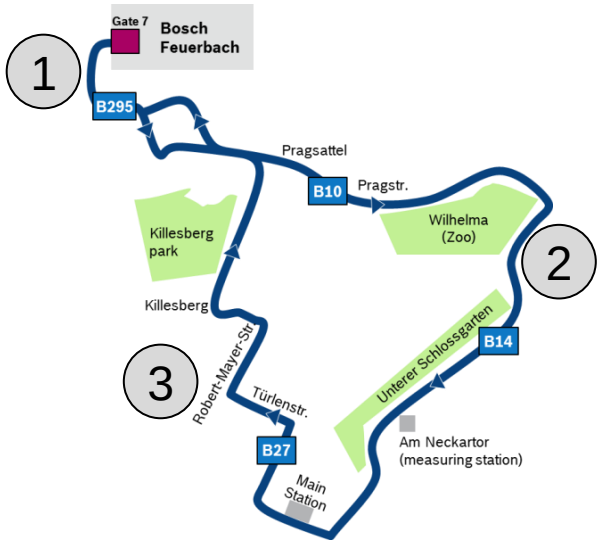
Bosch EU6-RDE Testing Conditions

Bosch Stuttgart Urban Track, Impr. Warm-up Management

Status March 2017 - - -

Status August 2017 - - -





Test track:	Stuttgart urban track
Distance:	16 km
Altitude gain:	≈ 1200 m/100 km
Test mass:	1550 - 1850 kg
EGT:	aged
Test cond.:	cold start only

BOSCH

Bosch Stuttgart Track
How measurements were made

Covering of normal traffic situations:

Bosch internal test:
“Stuttgart Track”

Urban < 60 km/h

Rural 60–90 km/h

Motorway 90–145 km/h

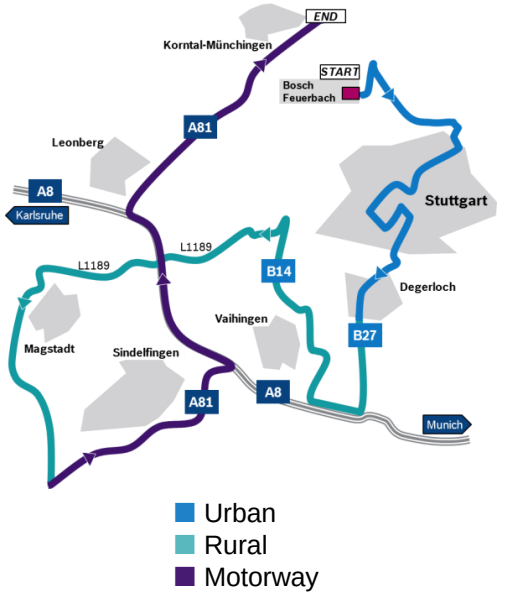
Each part must cover about 1/3 of total distance and more than 16 km, total duration: 90 – 120 min.
Separate evaluation of total trip and urban part

Cold start

Incline

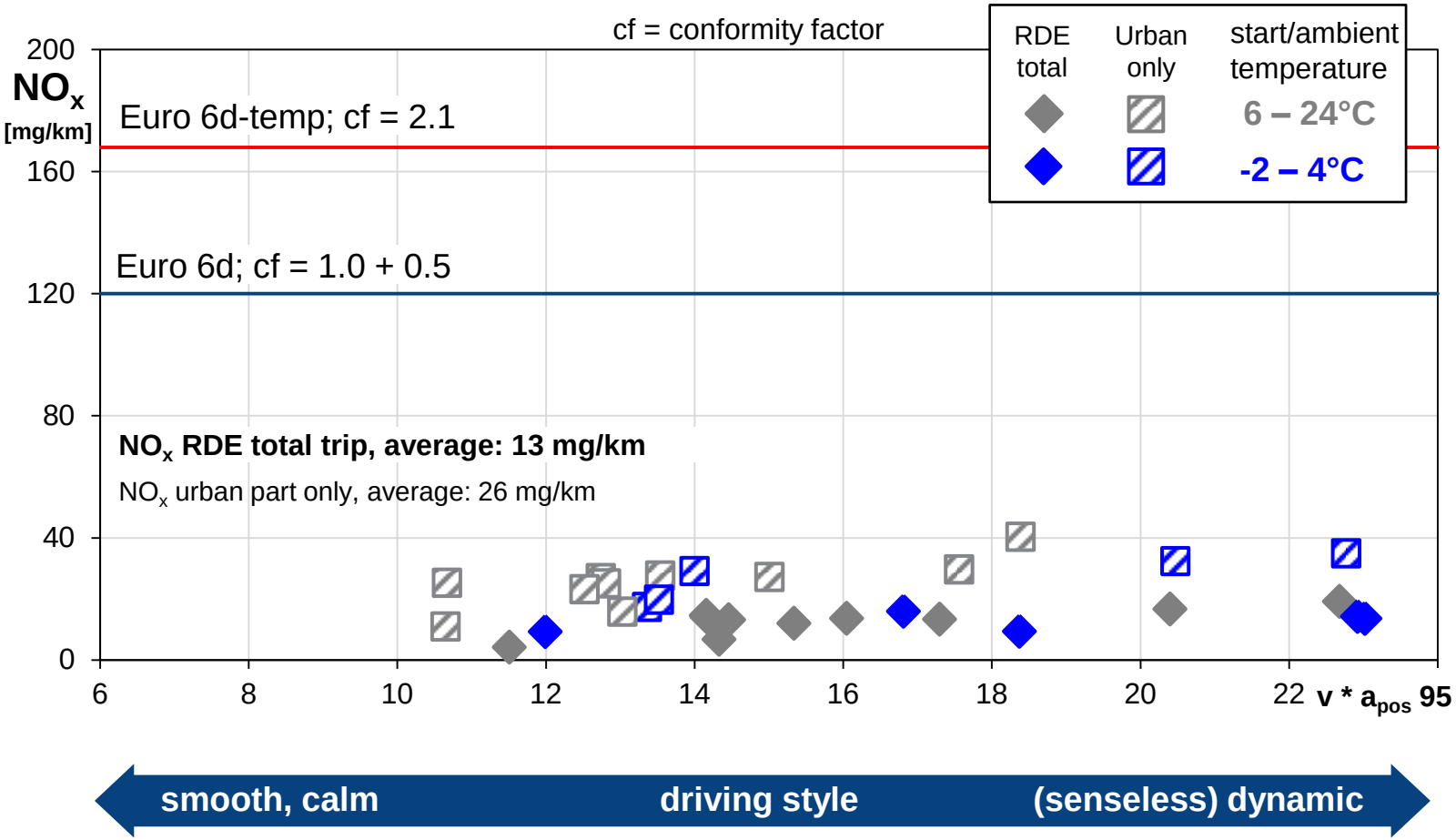
Pay load

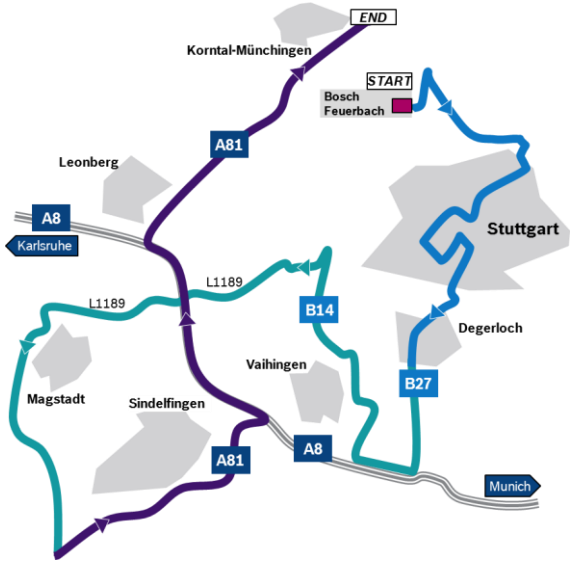
Driving dynamics



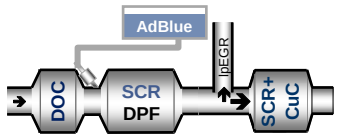
BOSCH

EU6-RDE On-Road Measurements
Bosch Stuttgart Track





SCR



Test track:	Bosch Stuttgart Track
Distance:	86 km
Altitude gain:	840 m / 100 km
Test mass:	1550 - 1850 kg
EGT:	aged
Test cond.:	cold start only

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EU6-RDE On-Road Measurements
Focus Bosch „Stuttgart Urban“ Track

City < 60 km / h

Rural 60 – 90 km / h

Highway 90 – 145 km / h

Most relevant for air quality is urban part

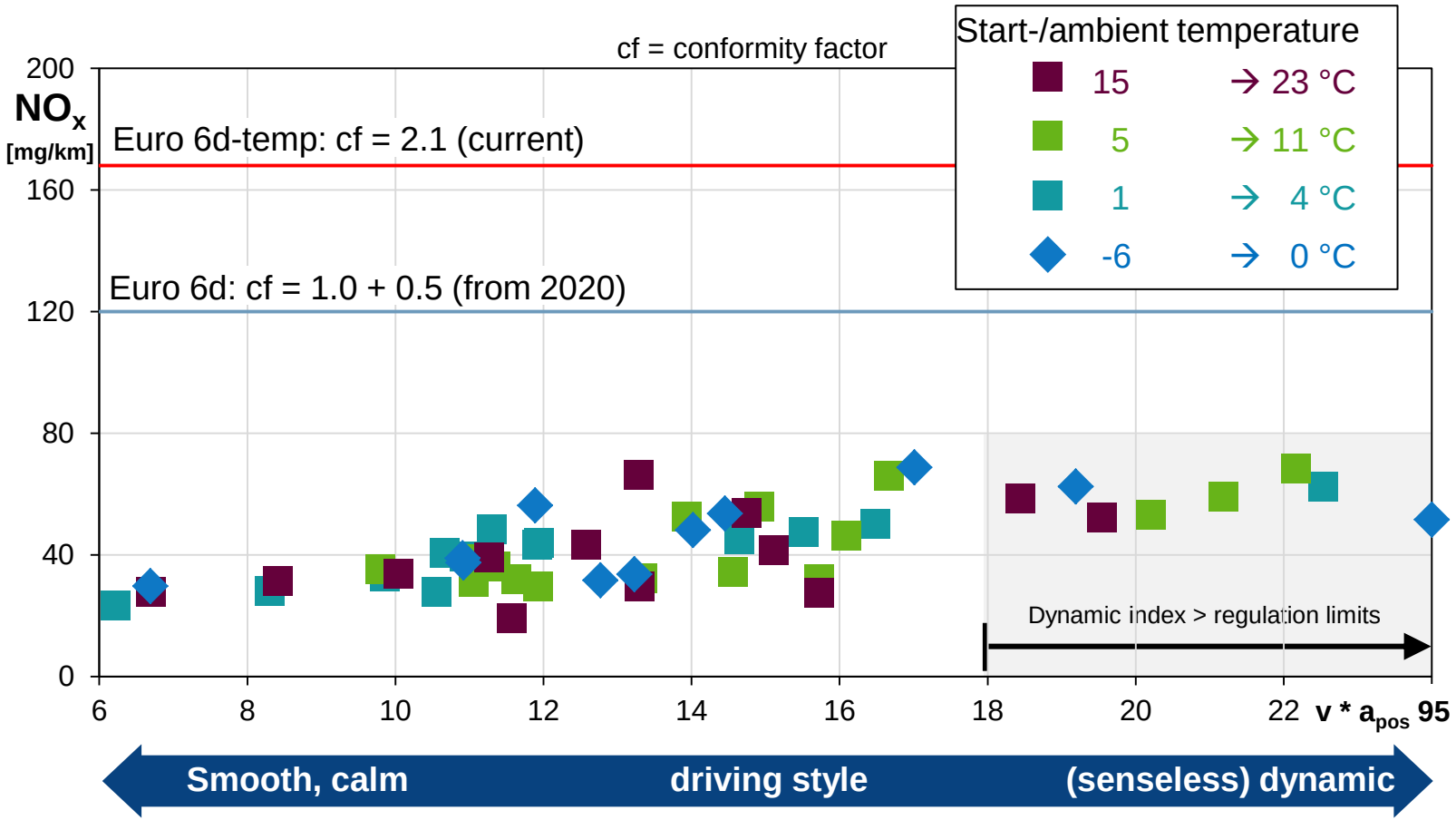
cold start	road gradient	vehicle payload	driving dynamics
all temperatures	1200 m / 100 km (upper limit)	up to max. payload	whole range

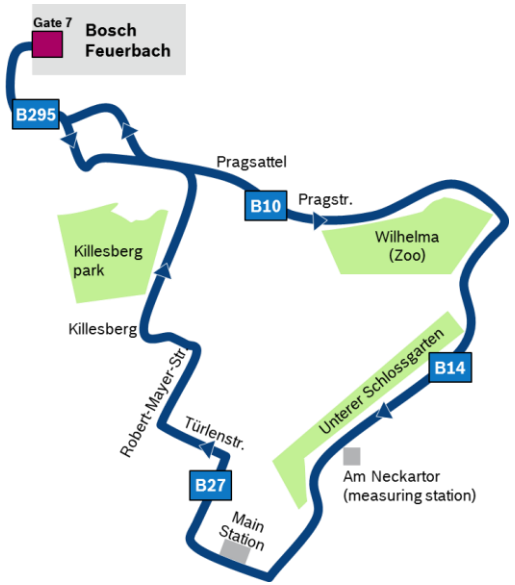
Bosch Test: „Stuttgart Urban“, very challenging boundary conditions

Stuttgart Urban Track

BOSCH

EU6-RDE On-Road Measurements
Focus Bosch „Stuttgart Urban“ Track





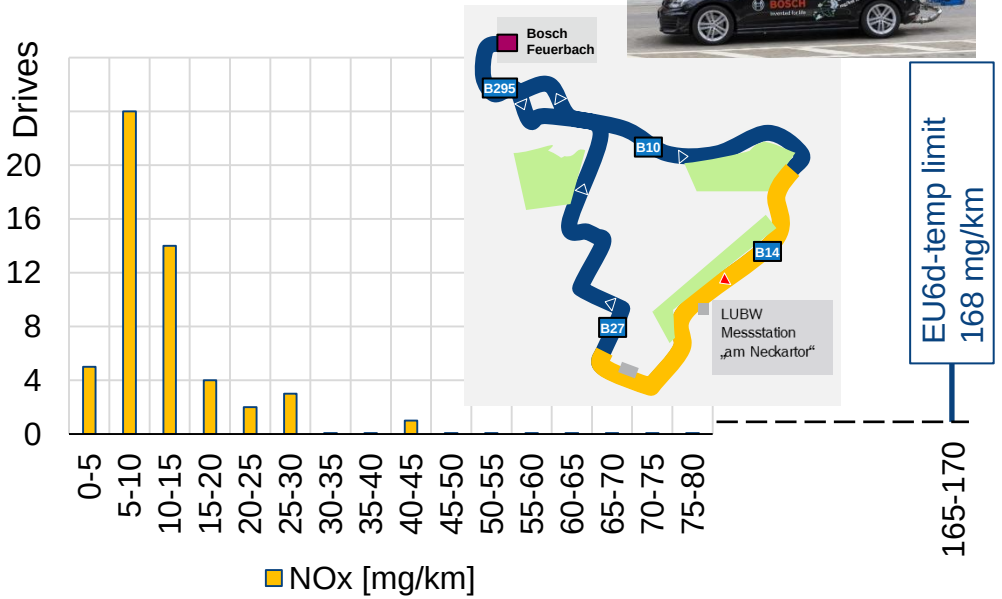
Test track:	Stuttgart urban track
Distance:	16 km
Altitude gain:	≈ 1200 m/100 km
Test mass:	1550 - 1850 kg
EGT:	aged
Test cond.:	cold start only

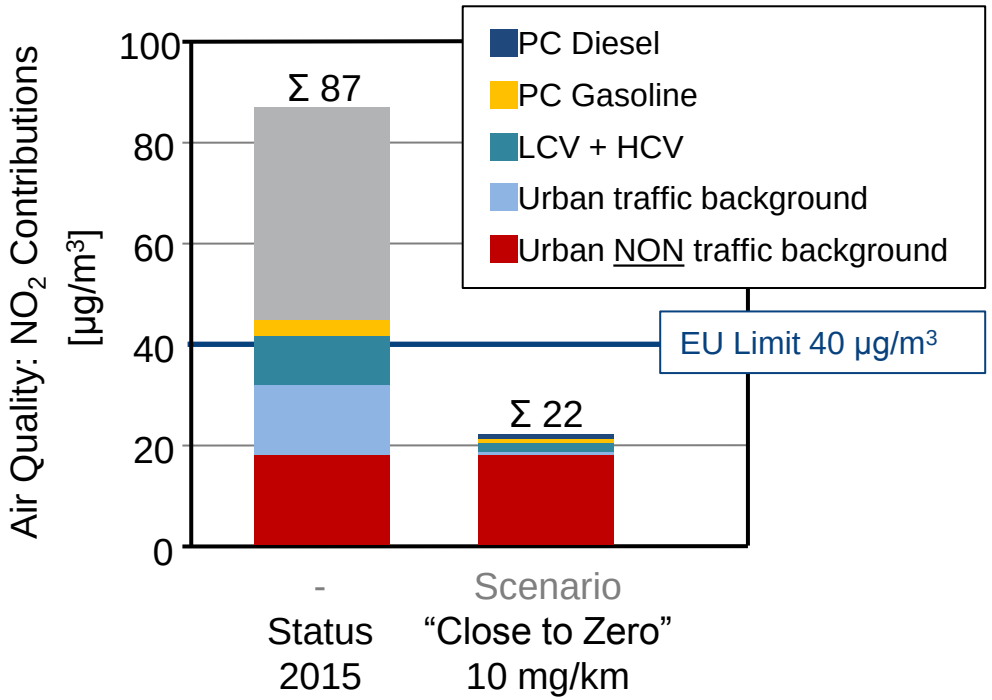
Transfer of Emission Results to Air Quality

Emission situation of demo vehicle @ “Am Neckartor”

Emissions → Air quality calculation → Immissions

Total EU6-RDE trip: ø 13 mg/km
At section Neckartor: ø 12 mg/km





The reduction of NO_x emissions will result in negligible NO_2 contribution of Diesel pass. cars to air quality.

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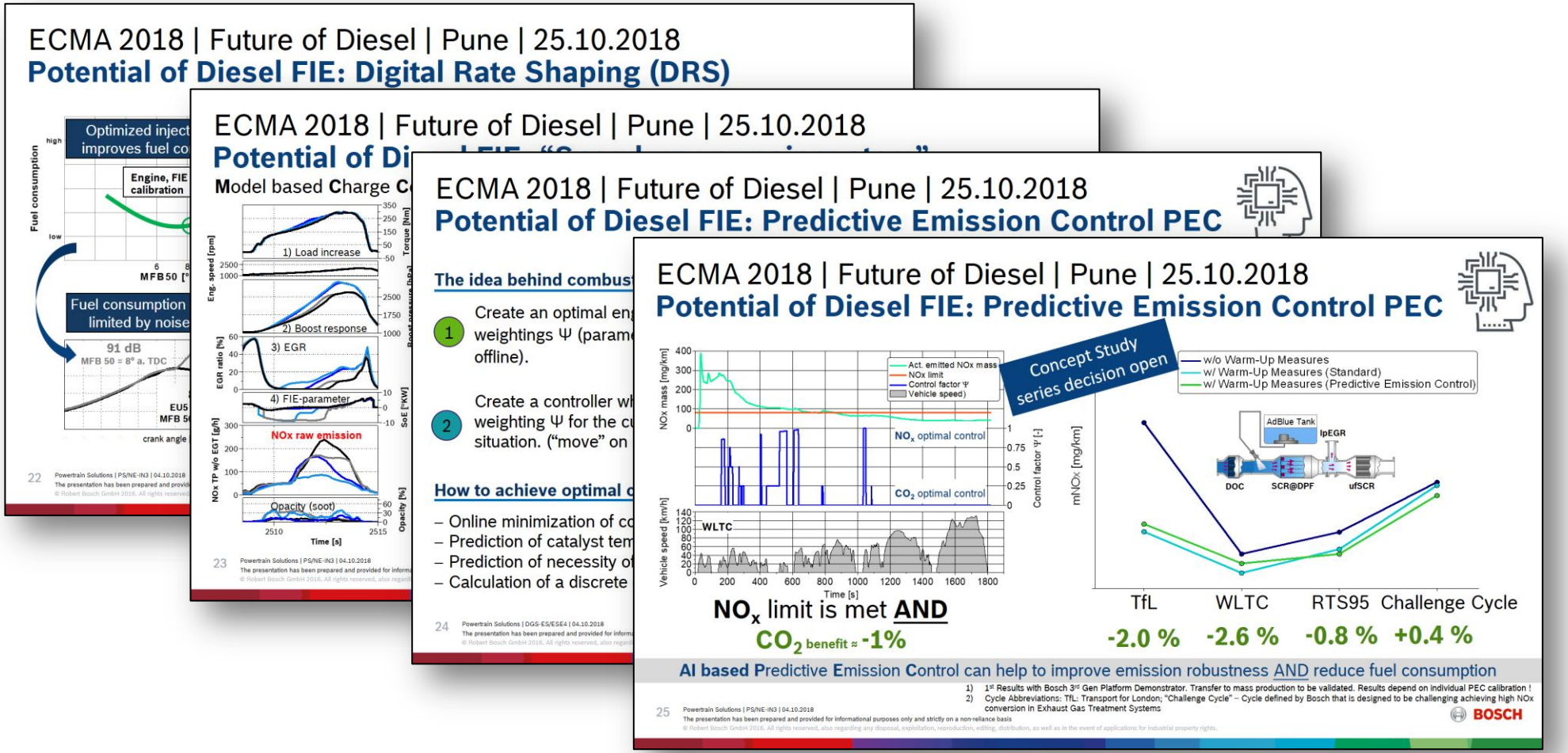
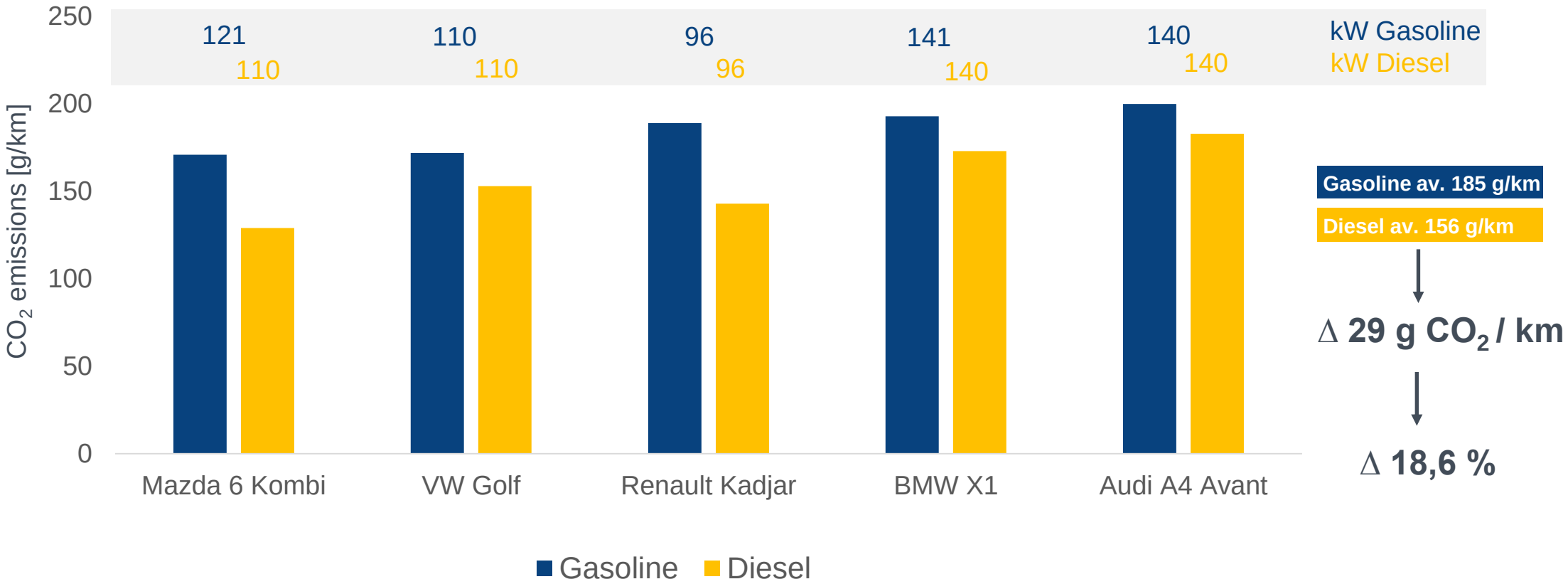
Smart approaches that helps to improve Emissions and CO_2



Latest results from EU

Benchmarking EU6 Gasoline vs. Diesel [1)]



Diesel Powertrain remains the more fuel efficient powertrain also after introduction of EU6 emission norms

1)Source: German Press - Auto Motor Sport dt. 15 06.07.2017

Affordable measures to reduce ICE CO_2 emissions

Gasoline
Diesel

Base BS4 Gasoline vehicle [Compact class]

Base BS4 Diesel vehicle [Compact class]

VVT
Variable Valve timing for exhaust

CRI 2-20 w/ DRS1
Higher Injection Pressure + Digital Rate Shaping (DRS I)

Friction reduction
Turbocharger with optimised Ball bearings/ Journal bearing
Smaller turbine e.g. T:C=1:1.3

TC friction reduction

GDI
GDI-TC Dz 20%, - 350bar
LP EGR with Turbocharger matching for lower pumping losses and better efficiency
APFI-TC, Dz20%, Miller, CEGR, CR+…1

APFI
C.EGR
miller

LP EGR + TC matching

BS6 gasoline vehicle with Engine measures

BS6 Diesel vehicle with Engine measures

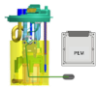
ISS
Idle Start Stop

ISS

IGC
Intelligent Generator Control with Passive boost and regenerative braking w/ alternator η improvement

IGC

DeCOS
Low pressure side Fuel control with Closed loop pressure signal



DeCOS

Oil Pump
Spring actuated ON-OFF valve
Full map control

Oil pump

Th. Management
Coolant Control Valve / Variable Water Pump, block cooling, two stage water temp. governor, Coolant circuit optimization

Th. Management

BS6 gasoline vehicle w/ eng.+ veh. Meas.

BS6 Diesel w/ eng.+ veh. Meas.

48V P0 system
48V Gen1 10kW, 170Wh (BOL)

BS6 Gasoline Hybrid [P0]

BS6 Diesel Conventional

Additional engine measures
Steel pistons

Frict. Red. (aux., belt)

Additional Vehicle measures
Aerodynamics

Vehicle weight optimisation

ICE's in India have a huge CO_2 reduction potential @ affordable costs.
Diesel will play a key role to meet CAFÉ targets

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Estimated fuel consumption burden to operate EGT to target BS6

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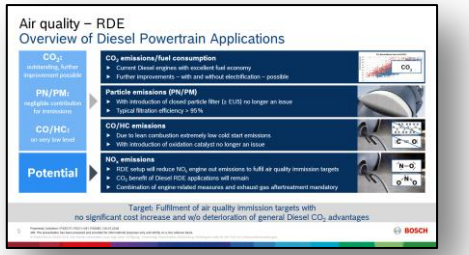
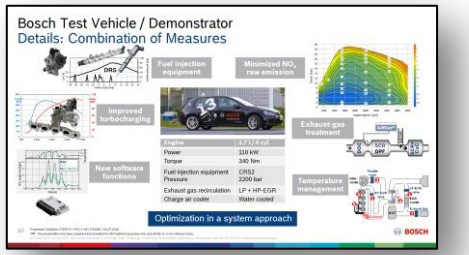
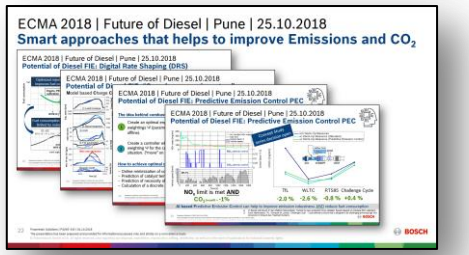
Wrap up







- Strong **increase in mobility demand** especially in India.
- **Mobility comes @ cost of emissions**.
- With introduction of BS6 in **2020 vehicular emissions of new vehicles expected to reduce significantly** (introduction of DPF, active NOx after treatment).
- **Bosch with it's 3rd Gen Diesel Platform demonstrator showcased[1)], that Diesel Powertrain has the potential to achieve low emissions, low fuel consumption @ affordable costs.**
- **Latest Real drive emission and fuel consumption results in EU confirm the competitive potential of Diesel powertrain[2)].**

1) Presentation A. Kufferath / Bosch during 39th Vienna Engine Symposia dt. 26.4.2018 "The Path to a Negligible NO_2 Immission Contribution from the Diesel Powertrain"
2) German Press: Auto Motor Sport dt. 15 06.07.2017 and ADAC ECO Test 09/2018 "EU6d-Temp Diesel sind sehr sauber"

Thank you for your attention

General Remarks

The presentation has been prepared and provided for informational purposes only and strictly on a non-reliance basis.

The presentation does not include any legal advice. Information regarding legislative and other regulatory requirements should be checked carefully on an independent basis.

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