CAR
CENTER FOR AUTOMOTIVE RESEARCH

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ROBERT BOSCH LLC

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Automotive Fuels and Emissions: Policies, Compliance and Potential Impact of Future Technologies

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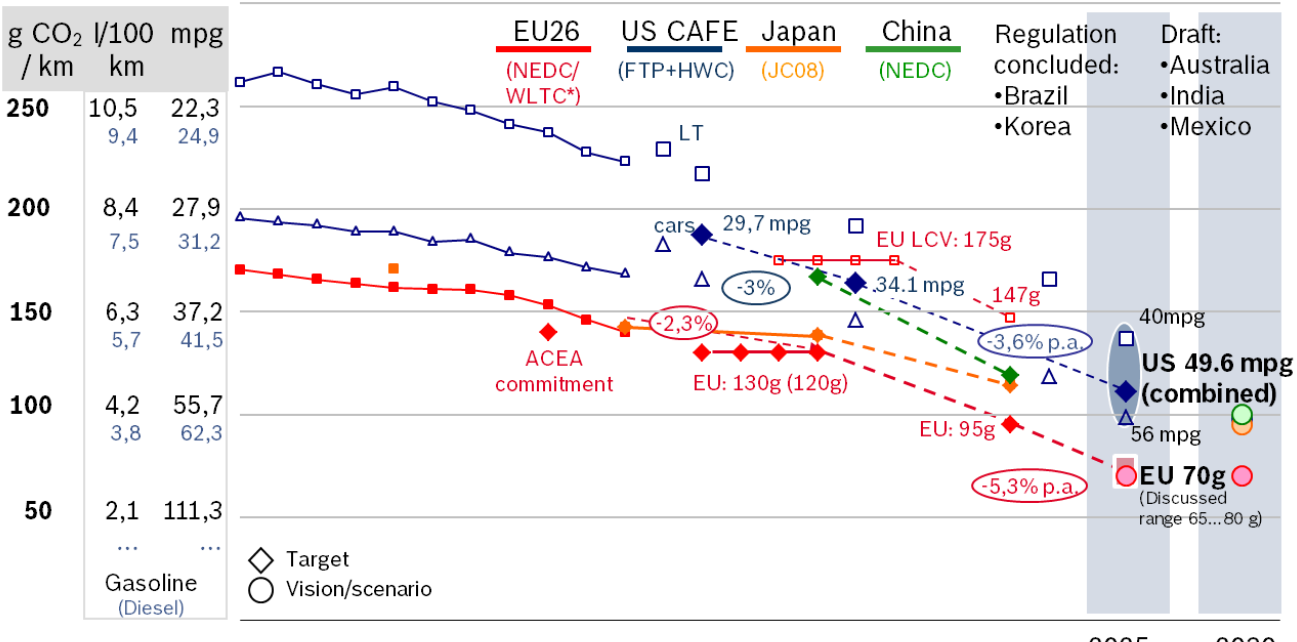
Global CO2 and FE fleet targets



CAFE = Corporate Average Fuel Economy LT = Light Trucks (pick-ups, vans, SUVs) NEDC = New European Driving Cycle FTP = Federal Test Procedure
HWC = Highway Cycle mpg = miles per gallon ACEA = Association des Constructeurs Européens d'Automobiles

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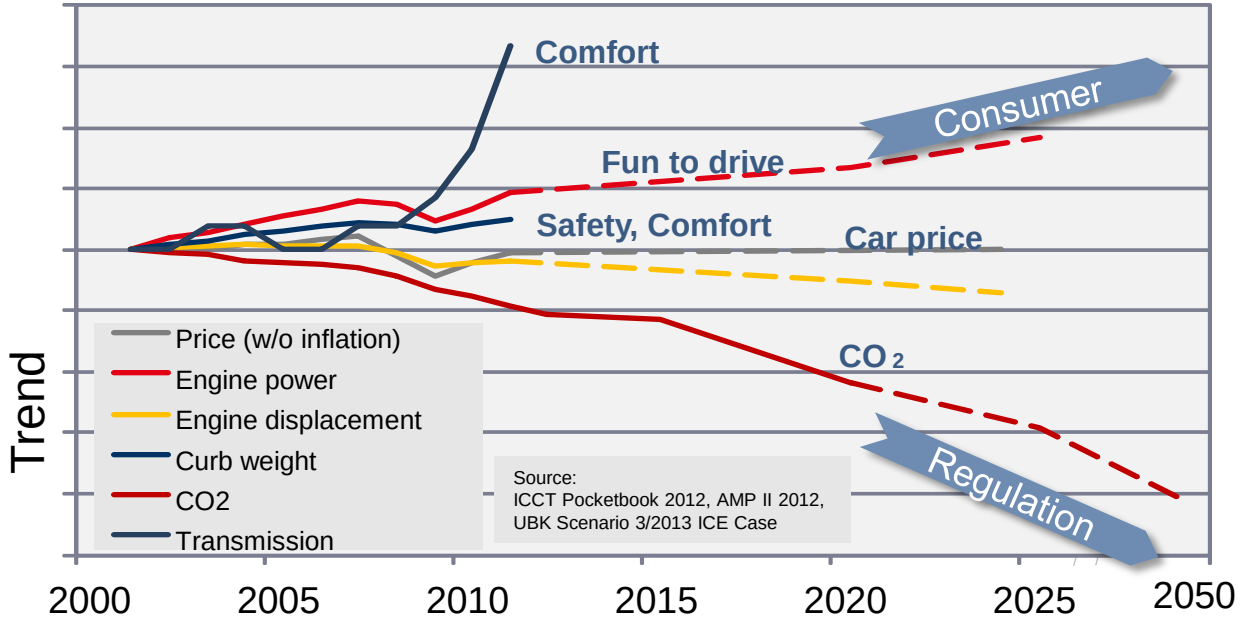
Motivation - Powertrain Market Drivers



Powertrain Optimization and Innovation have to bridge diverging requirements:
Long term CO_2 regulation vs increasing expectations of end customers

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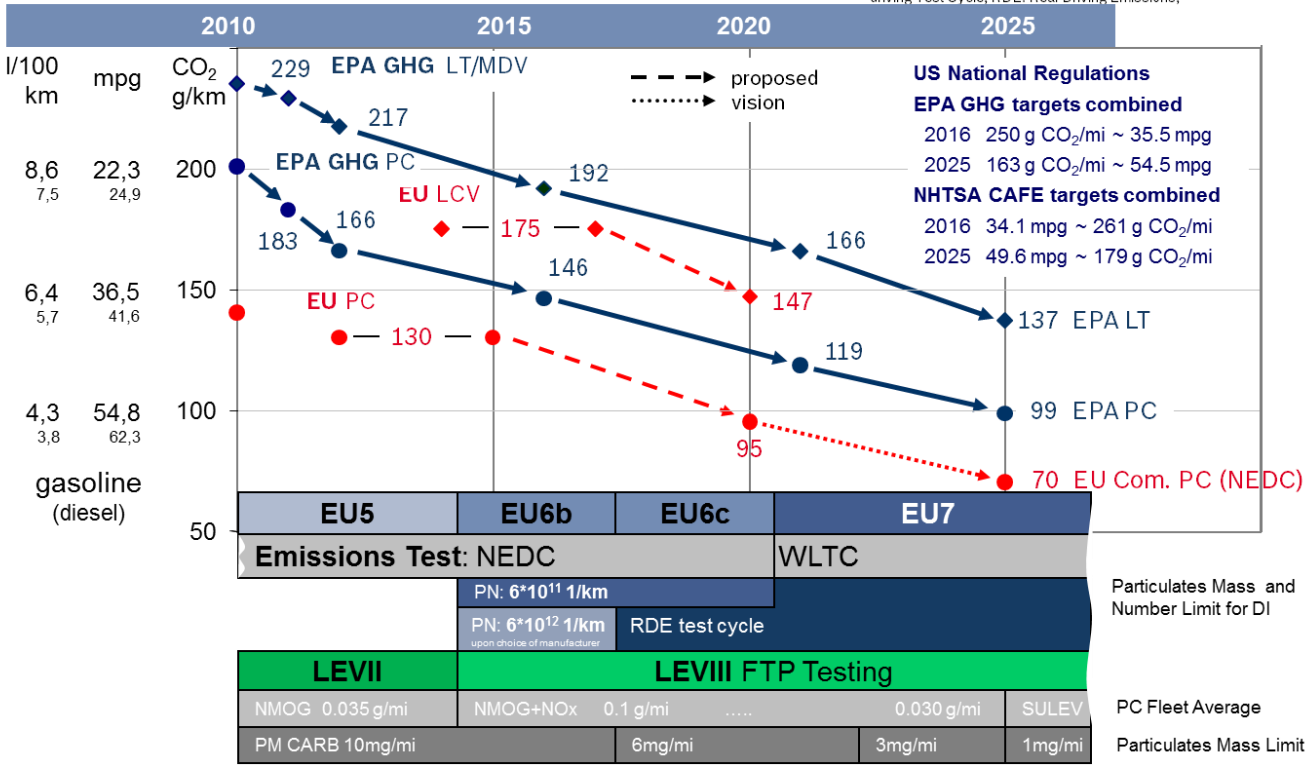
Fuel Economy & Emission Legislation

CAFÉ: Corporate Average Fuel Economy; PC: Pass; Cars LT / LDT: Light Trucks (pick-ups, vans, SUVs) ; MD(P)V: Medium Duty (Pass.) Vehicles LCV Light Commercial Vehicles, WLTC: Worldwide harmonized Light duty driving Test Cycle, RDE: Real Driving Emissions,



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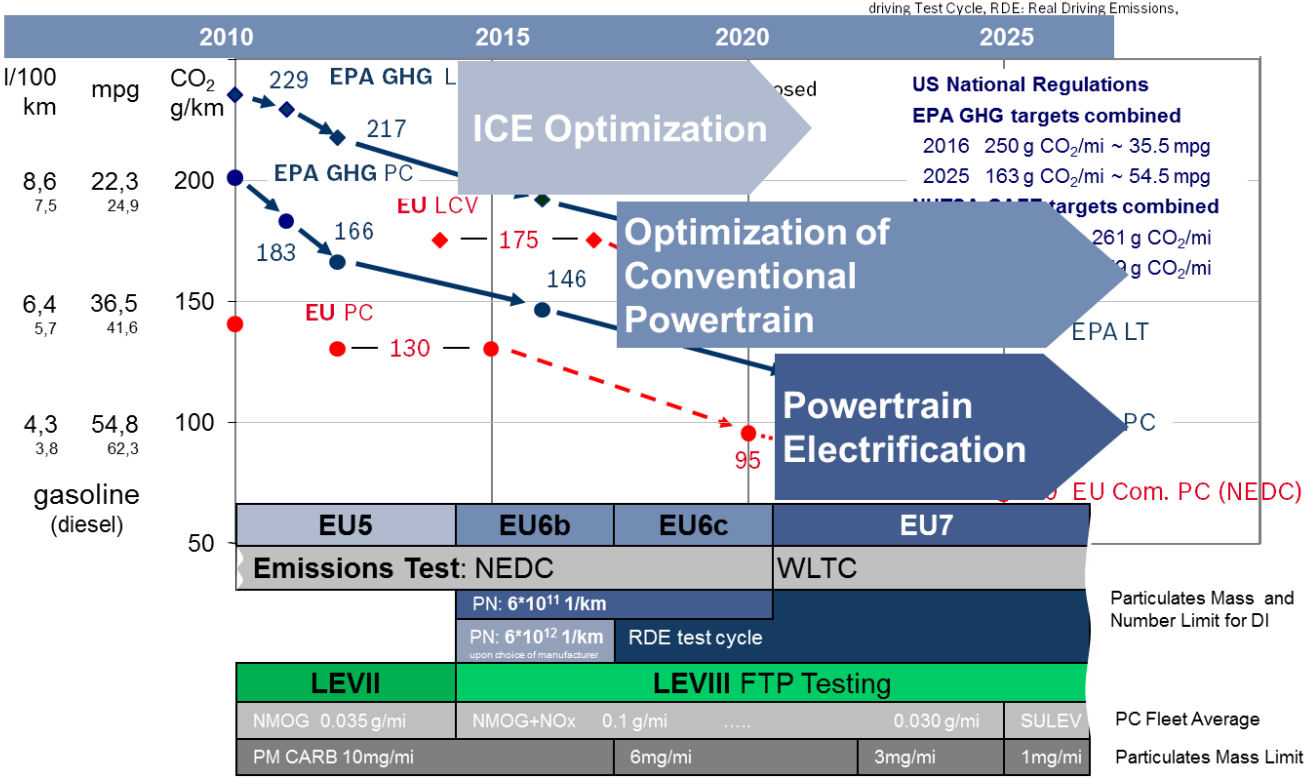
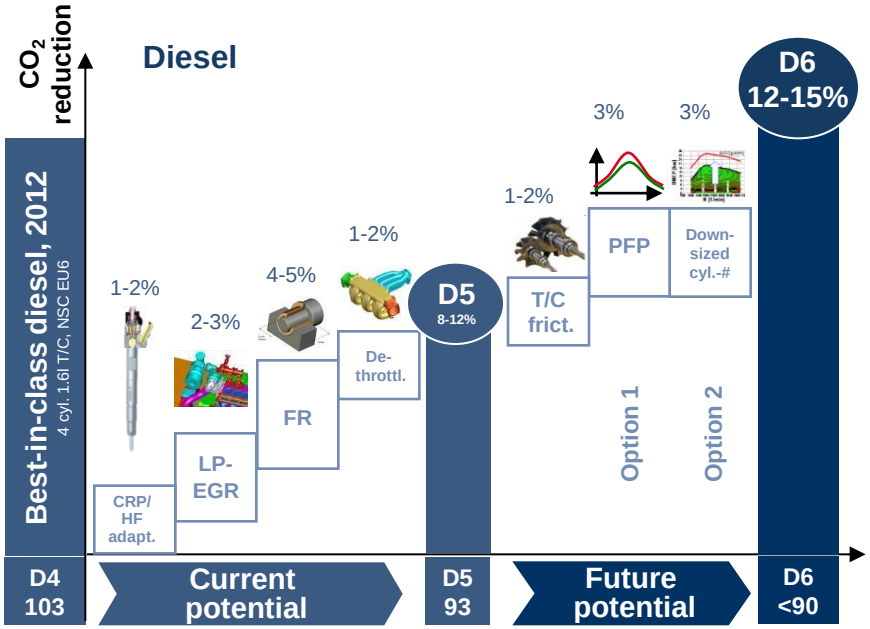
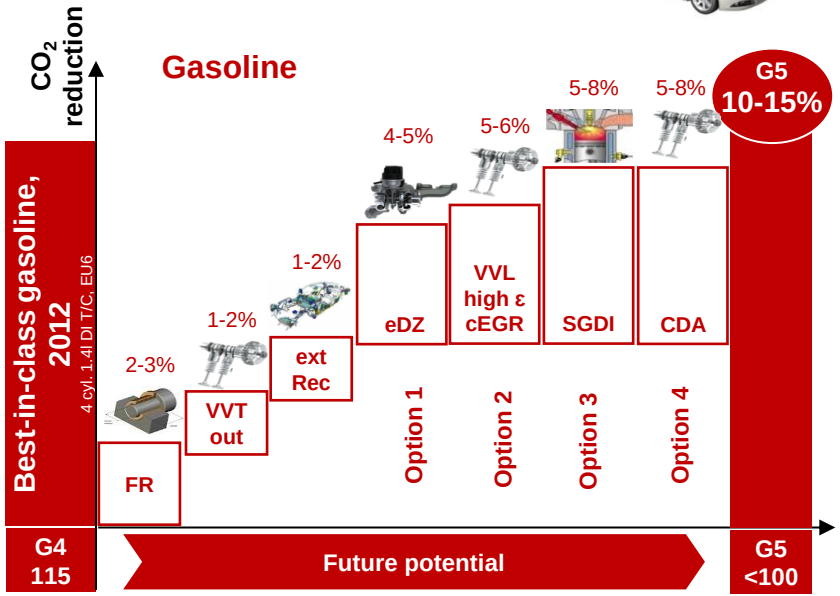


CO_2-reduction packages for compact class*





CRP/HF= common rail pressure / hydraulic flow | **LP-EGR**= low-pressure EGR system **FR** = friction reduction | De-Throttl. = de-throttling engine | **PFP**= low-peak firing pressure | **T/C** = turbocharger | **NSC** = NOx storage catalyst

VVT= variable valve timing | **SGDI** = lean burn | **FR** = friction reduction engine
eDZ = extreme downsizing | **VVL** = variable valve lift | **high ε** = high compression **cEGR** = cooled exhaust gas recirculation | **CDA** = cylinder deactivation
ext Rec = extended recuperation | **DI** = direct injection

Diesel and gasoline powertrains offer further CO_2-reduction potential of up to 15%

* 100 kW, 2020, NEDC

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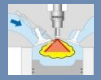
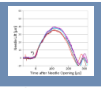
LEVIII Solutions for Gasoline Engines

Measure			Effect	
	Name	**Description**	**DI**	**PFI**
	High **P**ressure **S**tratified **S**tart 	**stratified mixture preparation @ start ⇒ reduced mixture enrichment**	HC ↓	-
	Homogeneous **Sp**lit Injection 	**mixture enrichment around spark plug @ catalyst heat-up ⇒ reduced HC raw emissions, increased exhaust heat-flow**	HC ↓ (PN, NO_x ↓)	-
	Laser Drilled High Pressure Injectors 	**laser drilling of HDEV holes ⇒ improved fuel spray characteristics (spray break-up, geometry and targetting)**	PN ↓ (HC,NO_x tbd)	-
	High Pressure Injector Controlled Valve Operation 	**compensation of HDEV fuel metering tolerances ⇒ improved accuracy of injected fuel mass**	PN ↓ (HC, NO_x tbd)	-
Advanced PFI	**R**educed **S**auter **M**ean **D**iameter 	**improved EV with reduced droplet diameter ⇒ improved mixture preparation**	-	HC ↓
	Demand **Co**ntrolled Fuel **S**upply 	**increase fuel pressure esp. @ start and warm-up ⇒ reduced droplet diameter of fuel spray**	-	HC ↓
	TWIN Injector 	**two injectors for each cylinder ⇒ improved fuel spray characteristics (Q_{stat}, spray targetting), increased exhaust heat flow**	-	HC ↓ (NO_x tbd)

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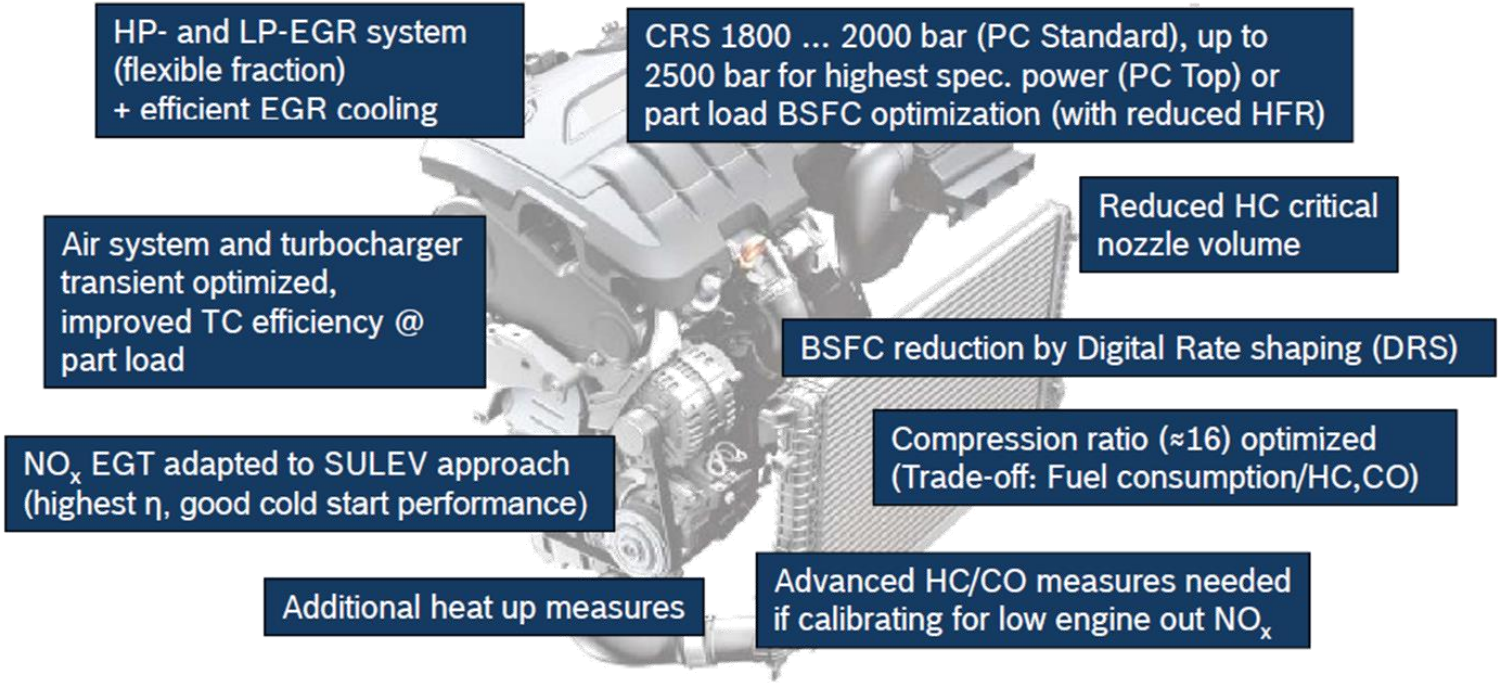
LEVIII Solutions for Diesel Engines



HP-/LP-EGR: High/low pressure exhaust gas recirculation; TC: Turbo charger; CRS: Common rail system; HFR: Hydraulic flow rate
BSFC: Brake spec. fuel consumption; EGT: exhaust gas treatment; NSC: NOx storage catalyst; SCR: Selective catalytic reduction

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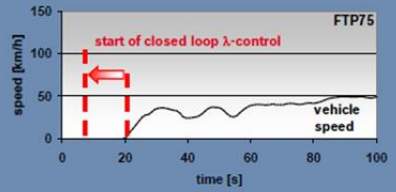
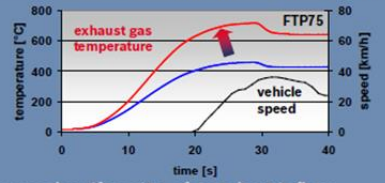
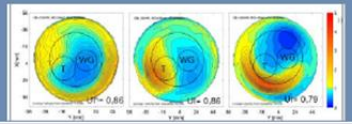
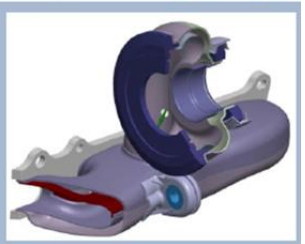
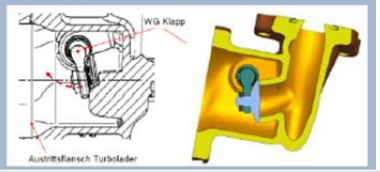
LEVIII Solutions with Turbo Systems

Challenge	Approach
Early Readiness of λ-Control 	**LSU adv pre TC** → LSU integrated in turbine inflow housing 
	LSU TSP → LSU with thermal shock protection (TSP) → combined with optimized position behind TC 
Rapid Catalyst Heat-Up → reduction of heat flow from exhaust gas into TC  → improved uniformity of catalyst inflow 	**Design and material of TC housing** → Design: Size / structure of surface contacted by exhaust gas → Material: cast iron vs. sheet metal 
	Design of waste gate and waste gate actuation → Opening angle of waste gate → Channeling of TC outlet flow 

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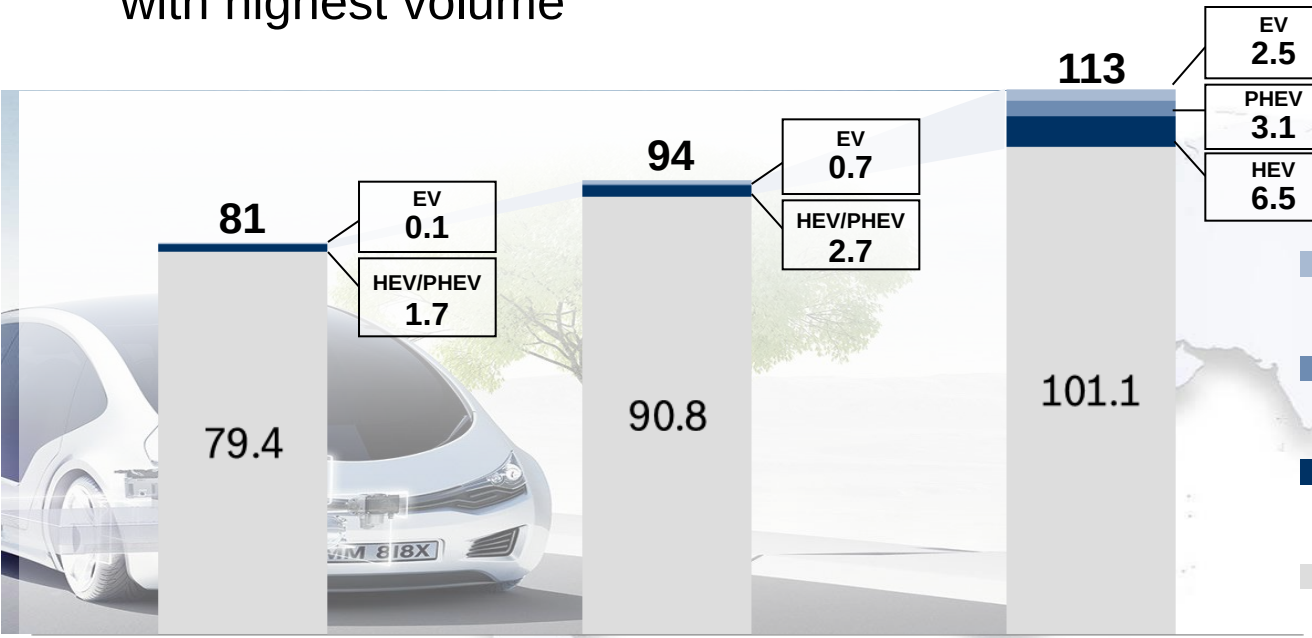
Powertrains with ICE stay dominant; PHEV will exceed EV by 2020, HEV with highest volume



EV
Electric vehicle

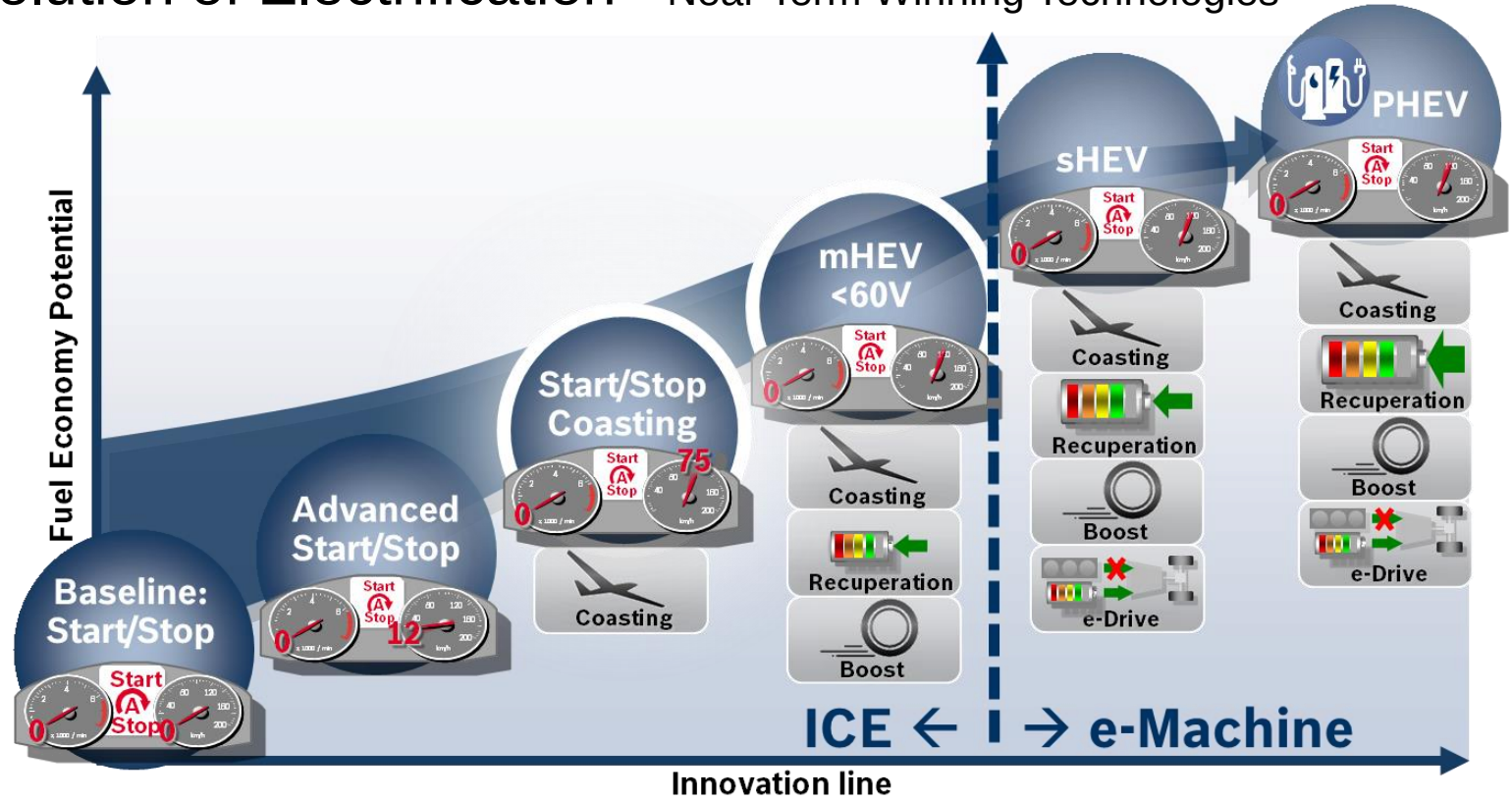
PHEV
Plug-in hybrid

HEV
Hybrid vehicle

Pure ICE
Internal combustion engine

Sales PC & LCV<6t (millions of vehicles)

Evolution of Electrification – Near Term Winning Technologies



Gasoline Systems mHEV: mild Hybrid - sHEV: Strong Hybrid - PHEV: Plug-In Hybrid

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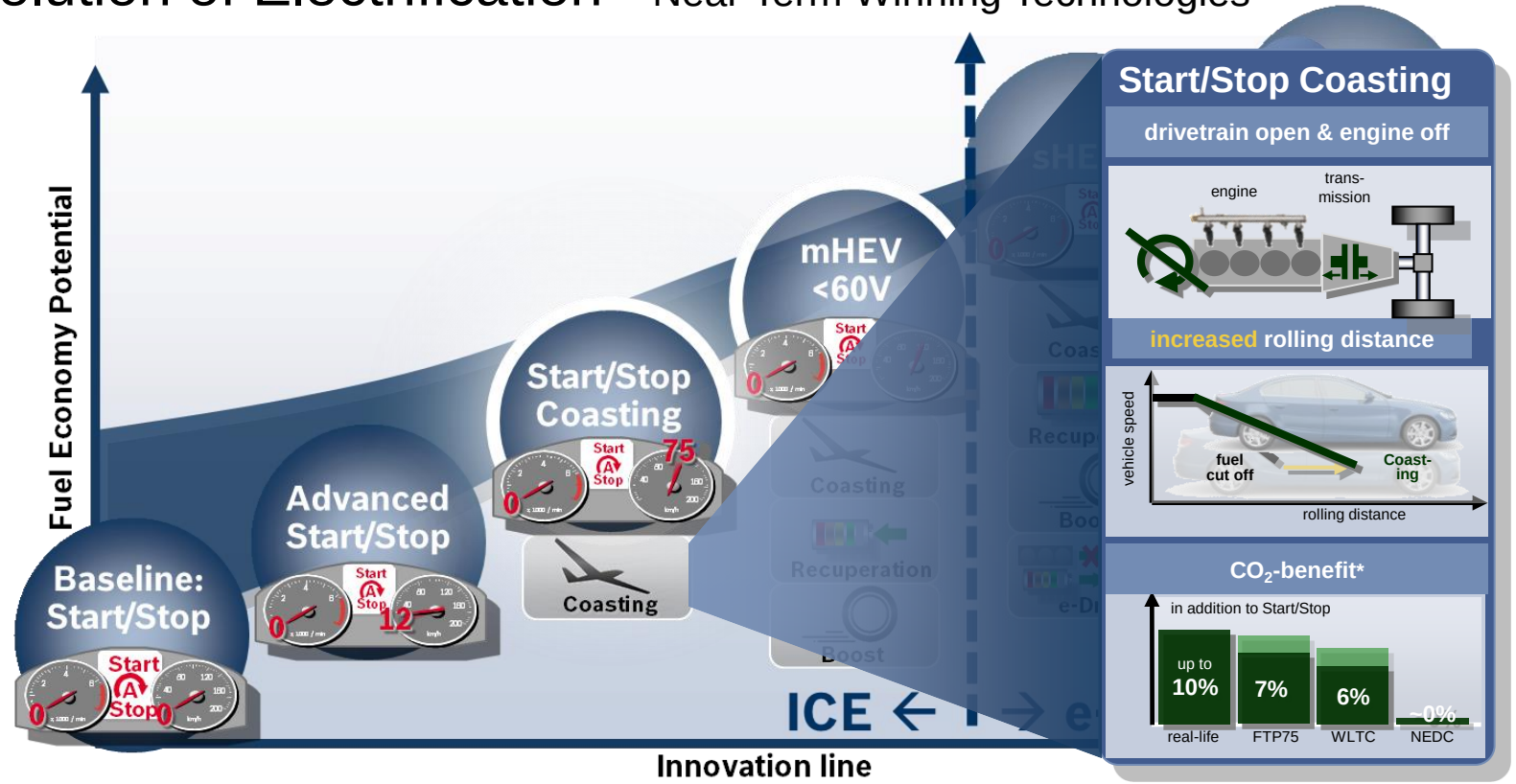
Evolution of Electrification – Near Term Winning Technologies



mHEV: mild Hybrid - sHEV: Strong Hybrid - PHEV: Plug-In Hybrid

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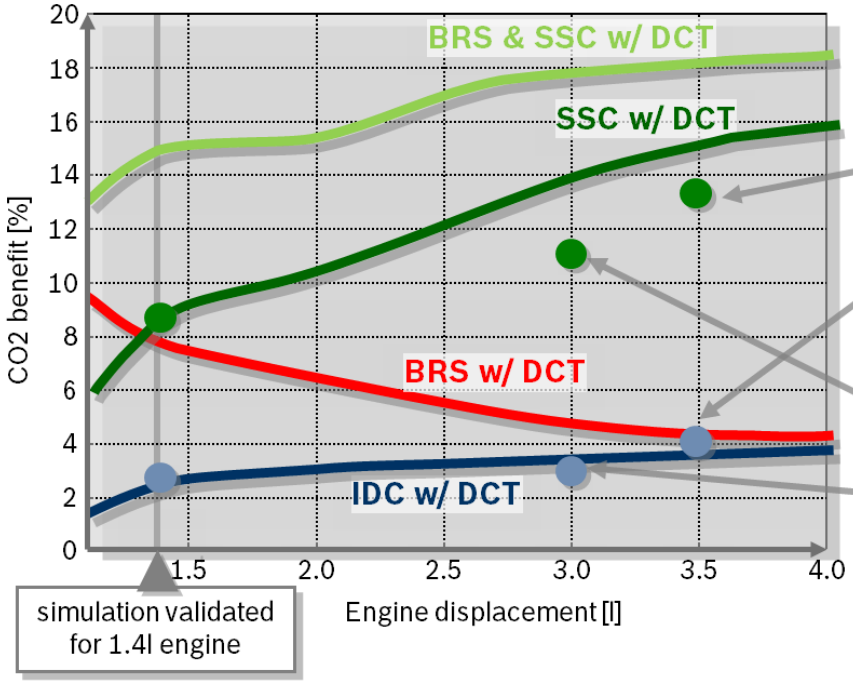
CO_2 Benefit of SSC & BRS



validated for: 3.5l engine, 1900kg, 7gear-automatic transmission w/ TC (AT)

validated for: 3.0l engine, 2315kg (SUV), 8gear-automatic transmission w/ TC (AT)

Baseline: compact class, 1500kg, gasoline, 7-gear DCT, Start/Stop, P_{el}=300W (power net), FTP75 (using speed tolerance band)

SSC and BRS show high synergy especially with high displacement engines

SSC…Start/Stop Coasting IDC…Idle Coasting BRS…Boost Recuperation System
AT…Automatic Transmission with torque converter

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Powertrain Architecture and Controls

Powertrain Sub-Domains

Efficient Combustion

Optimized Drivetrain

Affordable Electrification

Information Management

System Engineering Powertrain

Target → Optimized Powertrain Architecture with “Affordable Electrification”

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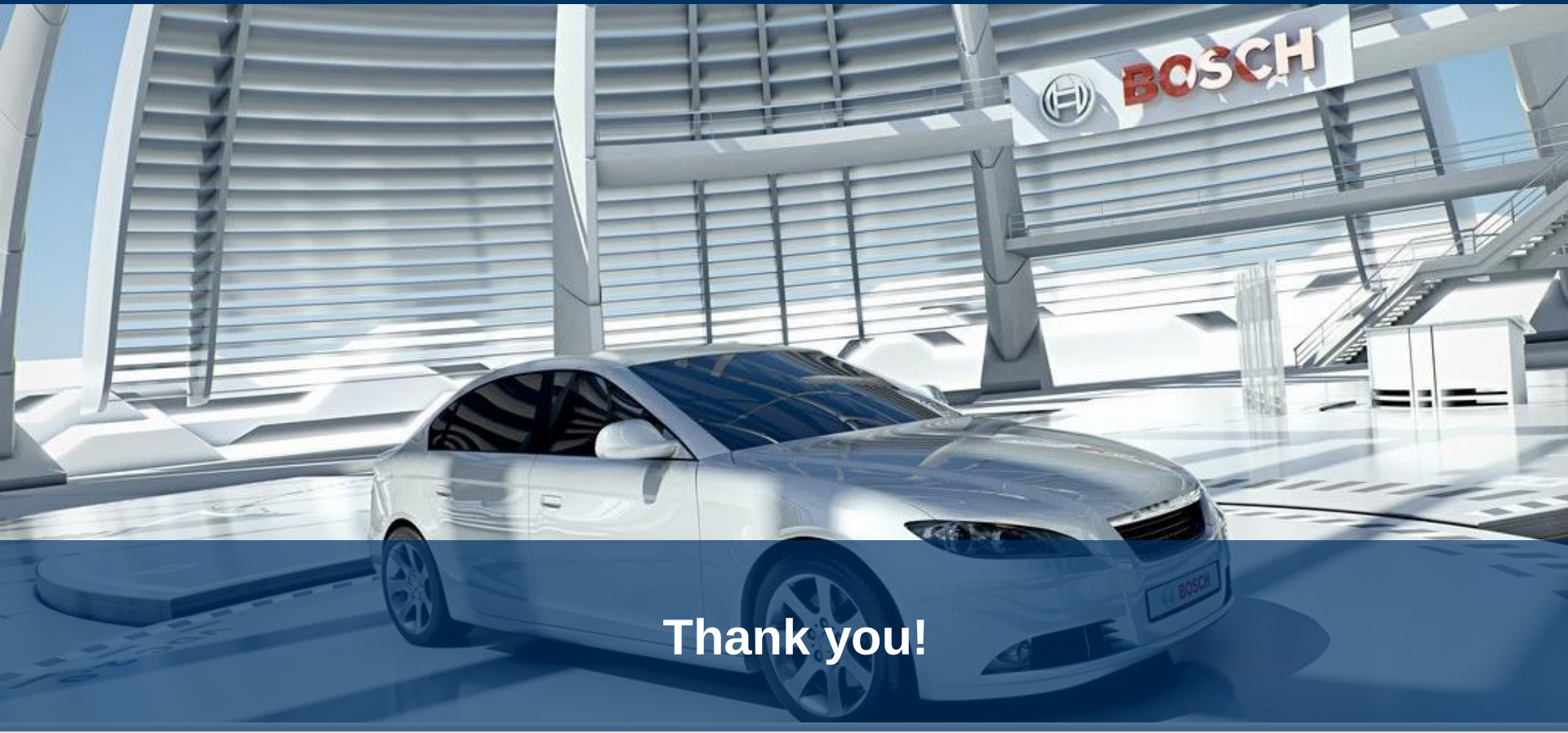

Thank you!

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