CAR
CENTER FOR AUTOMOTIVE RESEARCH

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AUTOMOTIVE FUELS AND EMISSIONS: Policies, Compliance & Potential Impact on Future Technologies

Das Auto.

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CAR Briefing December 5, 2013

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AGENDA

- Introduction to the VW Group
  - Global regulatory situation
  - Brief overview of Tier 3 proposed regulation and US regulations
  - Volkswagen Group engine strategy
    - Gasoline engines
    - Diesel engines
    - Engine strategy summary
  - Transmission strategy
    - DCT, automatic transmissions and electric drive gearbox developments
  - Electric Drive Strategy
    - Hybrids, PHEVs, BEVs
  - Fuel Policy
    - Market fuels and alternative fuels
- Summary of Tier 3 impact

VW GROUP PRODUCTS: NINE INDEPENDENT BRANDS

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Automotive Division

Passenger Cars

Volkswagen, Audi, SEAT, ŠKODA, Bentley, Bugatti, Lamborghini, Porsche, Ducati









Remaining companies

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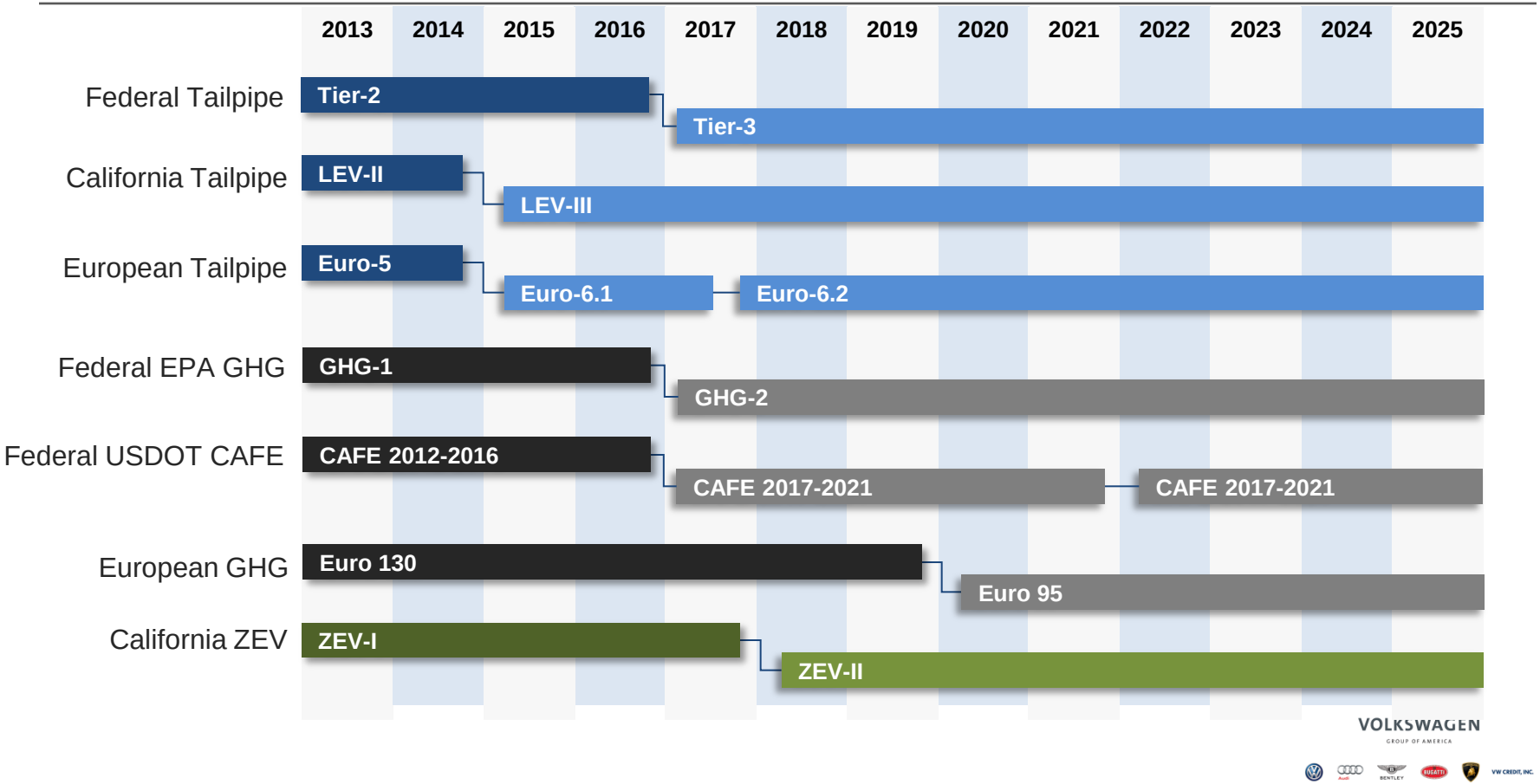
Volkswagen, Audi, Bentley, Bugatti, Lamborghini, VW Credit, Inc.

REGULATORY PROGRAM TIMING



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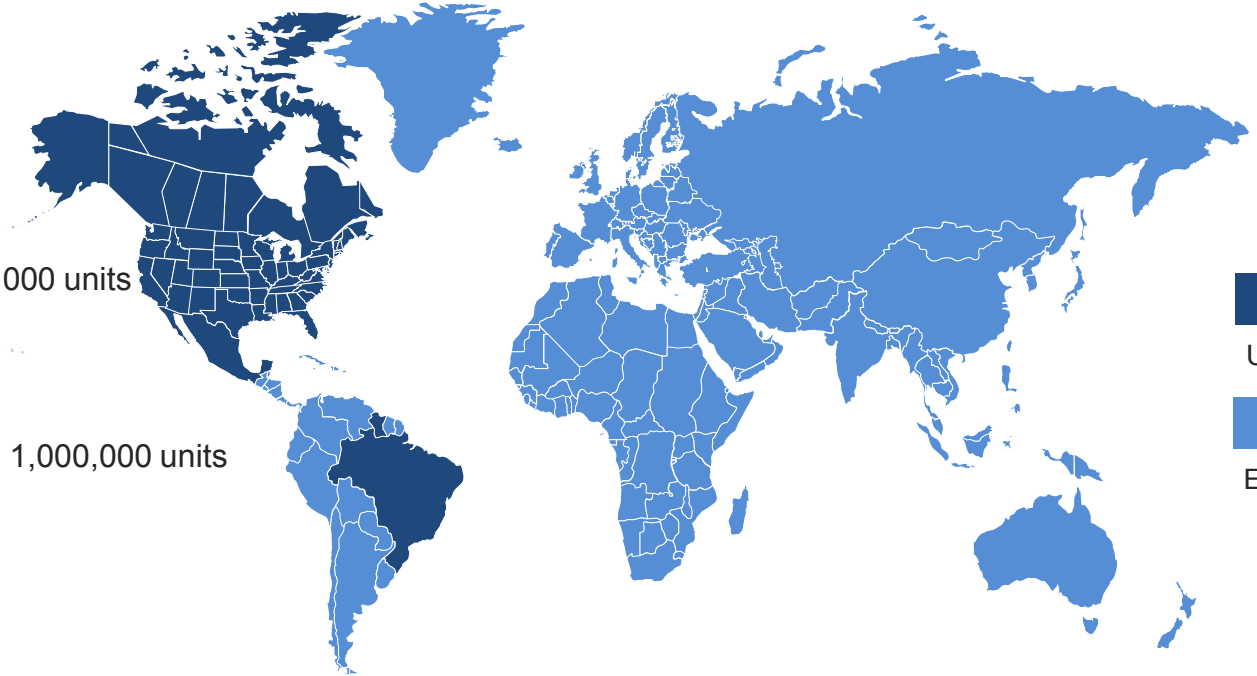
WORLDWIDE EMISSION PROGRAMS

Volkswagen Group targeting 10 million units per year Worldwide in 2018

NAR ≈ 1,000,000 units

SAR ≈ 1,000,000 units



US Based Emissions Stds

ECE Based Emissions Stds

20% of Worldwide Volkswagen sales comply with US Standards for emissions, the remaining 80% comply with ECE

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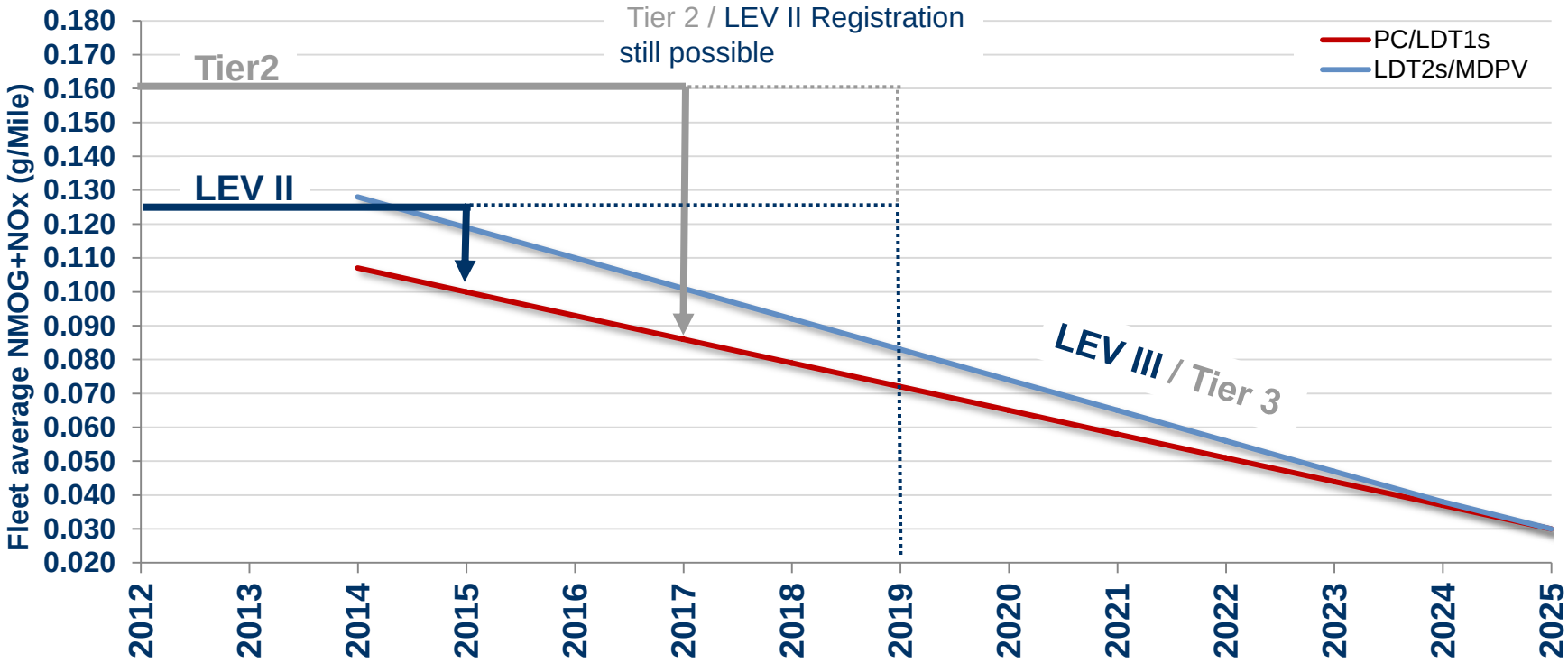
OVERVIEW OF US LEGISLATION

Model Year

Topic	Agency	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
CO2 Green-house gas + CAFE	EPA, NHTSA, CARB	Federal: National GHG / CAFE Legislation					National GHG/ CAFE regulation → 2040 = 0 gram CO_2						
		California + Sec.177											
Emissions (Federal: TIER California: LEV Low Emission Vehicle)	EPA	Federal: Tier 2			2017: Tier 3 (with Phase in)								
	CARB	LEV II	2015: LEV III (with Phase in)										
		California + Sec.177											
ZEV (Zero Emission Vehicle)	CARB	ZEV I				2018: ZEV II							
		California + ZEV States											

VW has to fulfil ZEV Legislation from 2018

TIER 3/LEV III FLEET AVERAGE PHASE-IN



NMOG = Non-Methane Organic Gas

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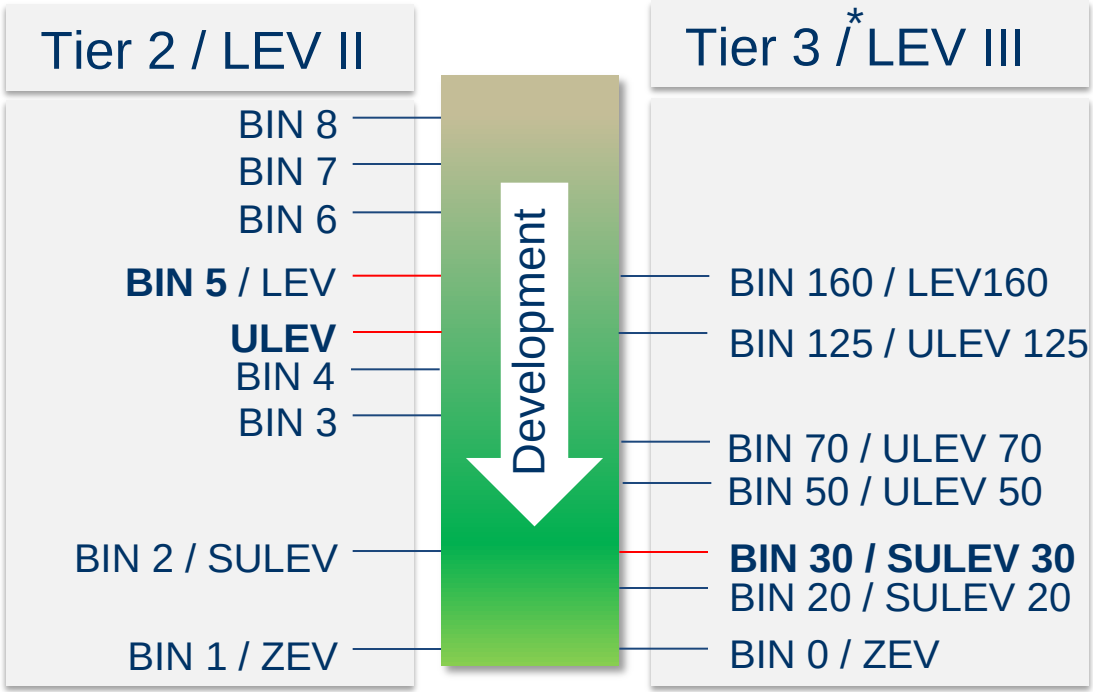
COMPARISON: TIER 2/LEV II WITH TIER 3/LEV III

Fleet average NMOG+NOx



* With extended warranty of 150k Miles / 15 years of emission relevant parts, agencies grant a bonus of 5mg/Miles. For example SULEV30 turns to SULEV25 because of that for the fleet calculation.

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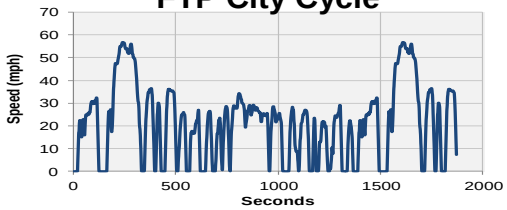
MANY ADDITIONAL ASPECTS TO THE TIER 3 REGULATION!!!

The NPRM (Notice of Proposed Rule Making) is 1450 pages

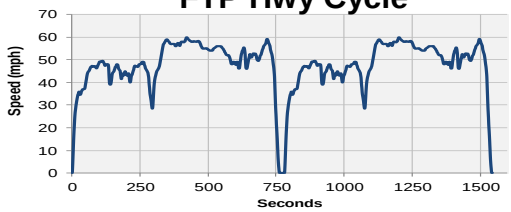
- FUL (Full Useful Life) extended from 120K to 150 K
- More stringent FUL SFTP standards
  - SFTP = Supplemental Federal Test Procedures – two additional test cycles for “off-cycle” emissions
    - US06 test cycle for high speed/high load
    - SC03 for air conditioning testing/micro-transients
  - Option for fleet average NMOG + NOX with similar FTP compliance curve
- New “Zero” evaporative emission standards
  - Fleet average compliance to very low whole vehicle emission levels
  - New canister bleed test to check evaporative emission system
- Lower PM standards on both the FTP (3mg/mile) and the US06 cycle (10 mg/mile)
  - Potential measurement/compliance issue
  - Potential disagreement with California – FTP (1mg/mile), US06 (4 mg/mile)
- Part 1066: New CFR section to handle revised testing and measurement techniques
- New certification fuel with ethanol content
- New market fuel with reduced sulfur

US TEST CYCLES

FTP City Cycle



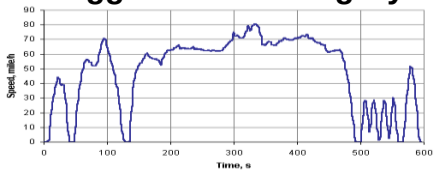
FTP Hwy Cycle



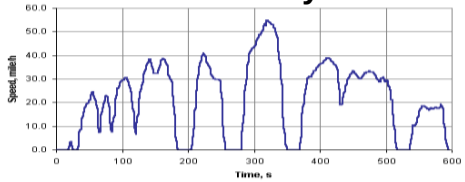
2 Cycle test

Used for:
- CAFE mpg targets
- NMOG +NOx FTP fleet average
- GHG fleet average

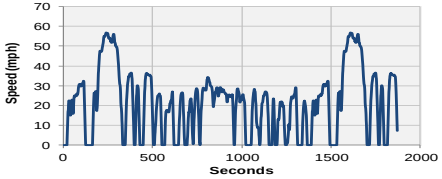
US06- Aggressive Driving Cycle



US03- A/C Cycle



FTP- Cold Ambient Cycle (20 F)



5 Cycle test

Used for:
- Monroney sticker (EPA mileage)
- NMOG + NOx **S**FTP average (excluding FTP-Cold Ambient Cycle)

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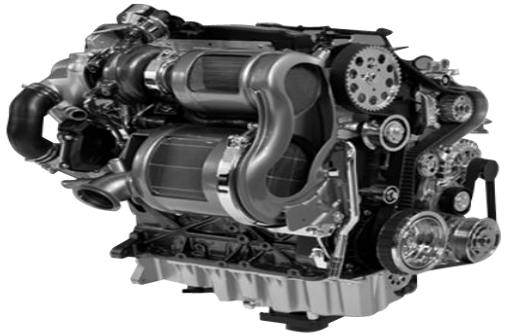
ENGINE STRATEGY OVERVIEW

EA 211

1.4L (1.0L – 1.6L)

EA 888 Gen3

1.8L (1.6L – 2.0L)



EA 288 MDB

2.0L (1.6L – 2.0L)

Three engines will be central to VW Group powertrain strategy – all four cylinder engines

- Recently developed for worldwide deployment
- Modular construction and adaptable to various emissions concepts
- Two gasoline engines, one diesel engine
- All three have direct injection, turbocharging and innovative valve timing/actuation

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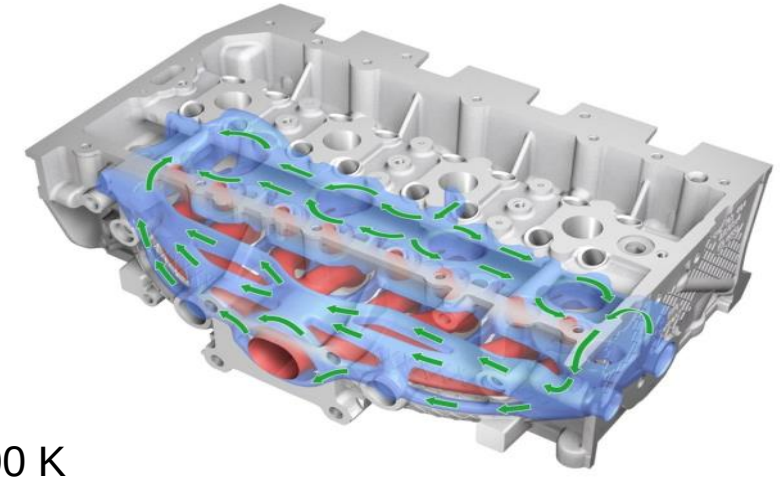
TECHNOLOGIES: EA 211 ENGINE

CO_2-optimization - iAGK cylinder head

4-valve cylinder head

- Integral exhaust manifold
- Cross-flow cooling
- 5 mm valve guide



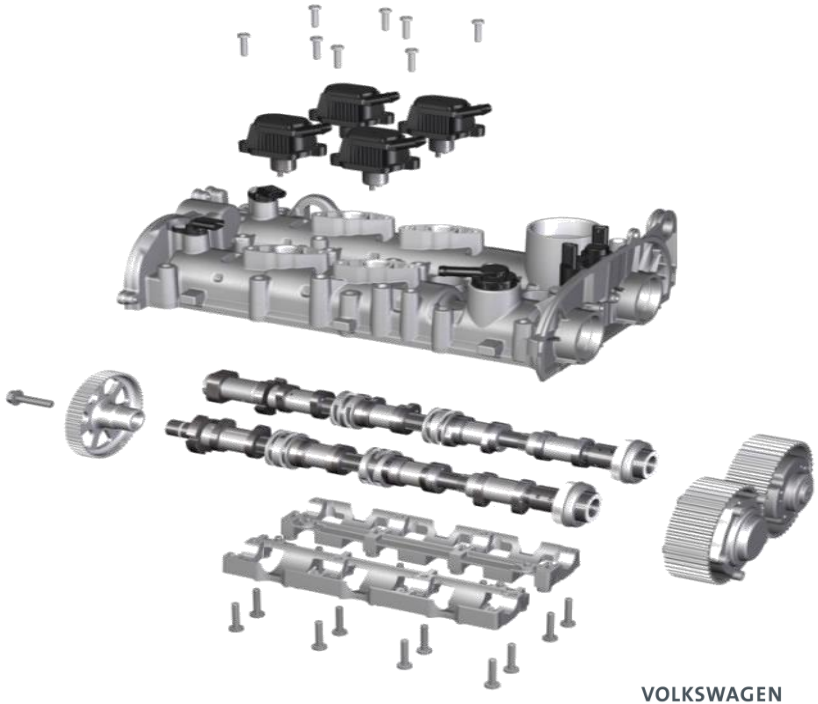
- Faster engine heat-up
- Faster cabin heat up
- Reduction of exhaust temperature by 100 K
- Reduction of fuel consumption by up to 2l / 100km at Top Speed

TECHNOLOGIES: EA 211 ENGINE

Cylinder shutdown - Rocker cover module

Assembly & function

- Installed space compatible with basic version
- Double-pin actuators for cylinders 2/3
- Inlet and exhaust camshaft adjusters
- Integral HDP drive
- Integral water pump drive
- Splined shafts and cam sections manufactured by VW
- Anti-friction bearing on drive side
- Reduced braking torque when coasting
- Engine start-stop function when vehicle is at a standstill



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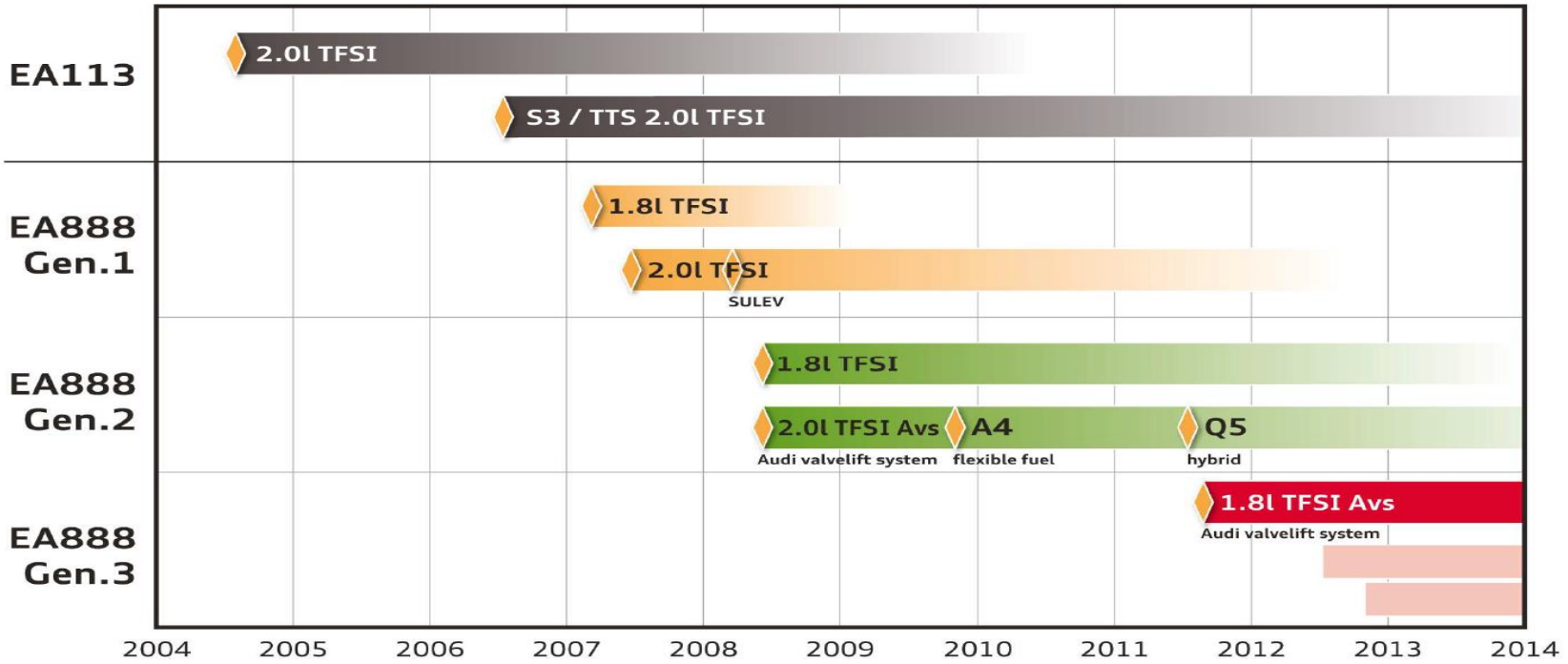
TECHNOLOGIES (EA 888) – Roadmap for direct injected engines



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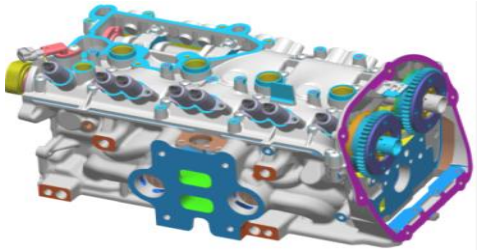
TECHNOLOGIES EA 888: US VOLUME VERSION



Cylinder Head

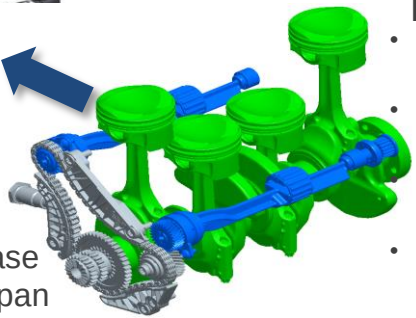
- Integrated Exhaust Manifold: significant Increase of customer mpg
- 200 bar High Pressure Injection
- Weight reduction on turbine housing
- Electric wastegate

Simple Exhaust Camshaft

Intake Manifold without MPI Injectors

Friction Reduction

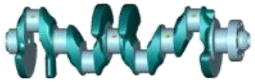
- Balance shaft roller bearing
- Smaller main bearings Reduced Oil pressure level
- Reduced tensioner forces



Thermostat

US- specific Components
To be updated with future stringency of GHG Rules

Lightweight Crank



- Thinwall crankcase
- Plastic lower oil pan
- Crankshaft with 4 counterweights
- Aluminum Screws

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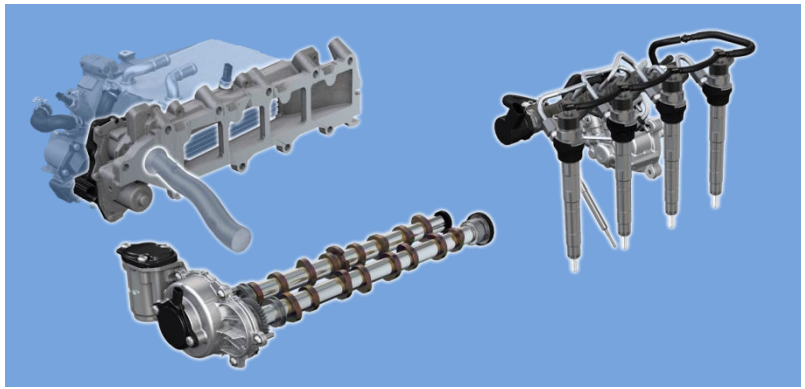
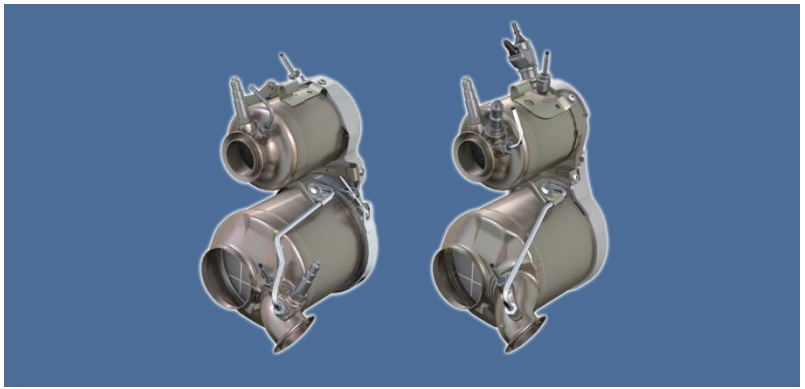
THE MODULES OF THE EA 288 TIER 3 ENGINE

Modules basic engine



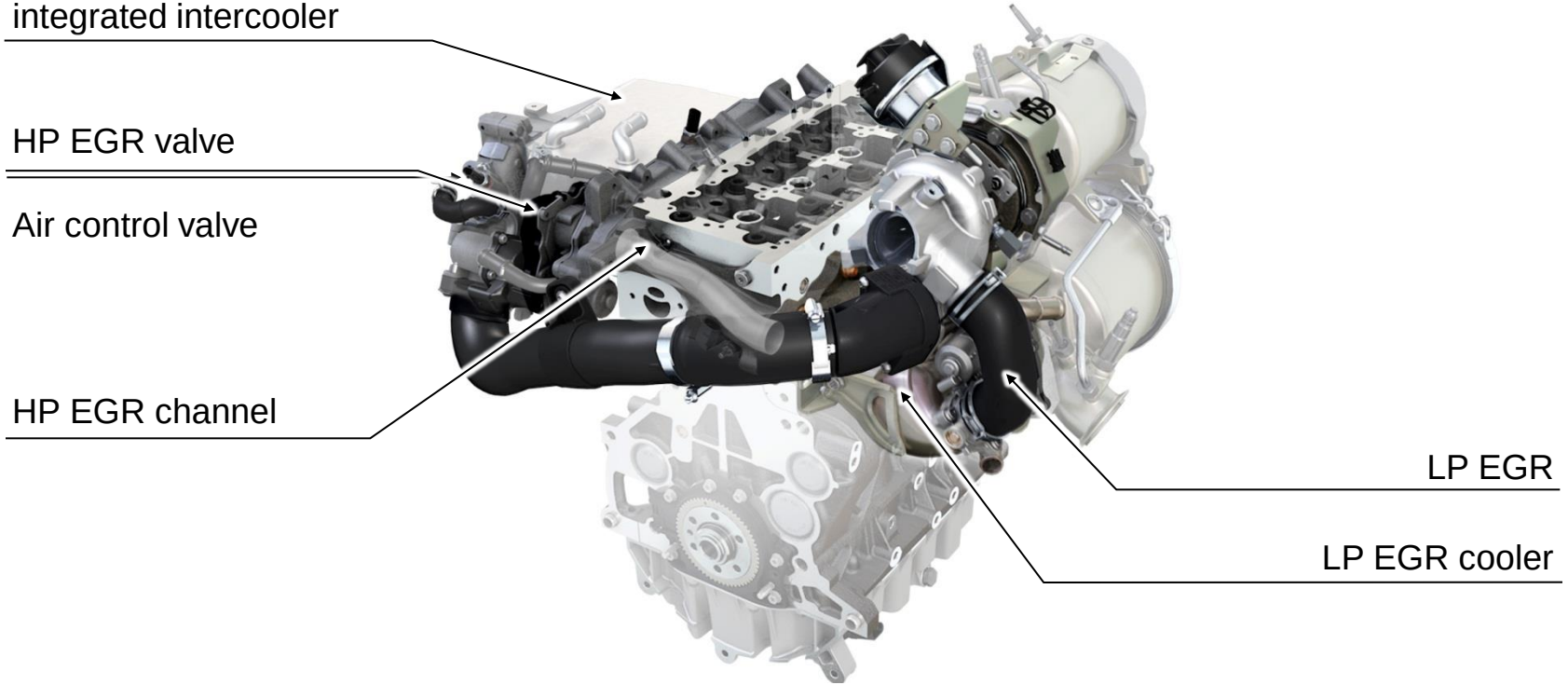
- HP EGR w/o cooler
  (channel through cylinder head)
- Variable valve train (VVT)
- Cylinder pressure control 2nd generation
- 2000 bar high-pressure injection system

Modules exhaust gas aftertreatment



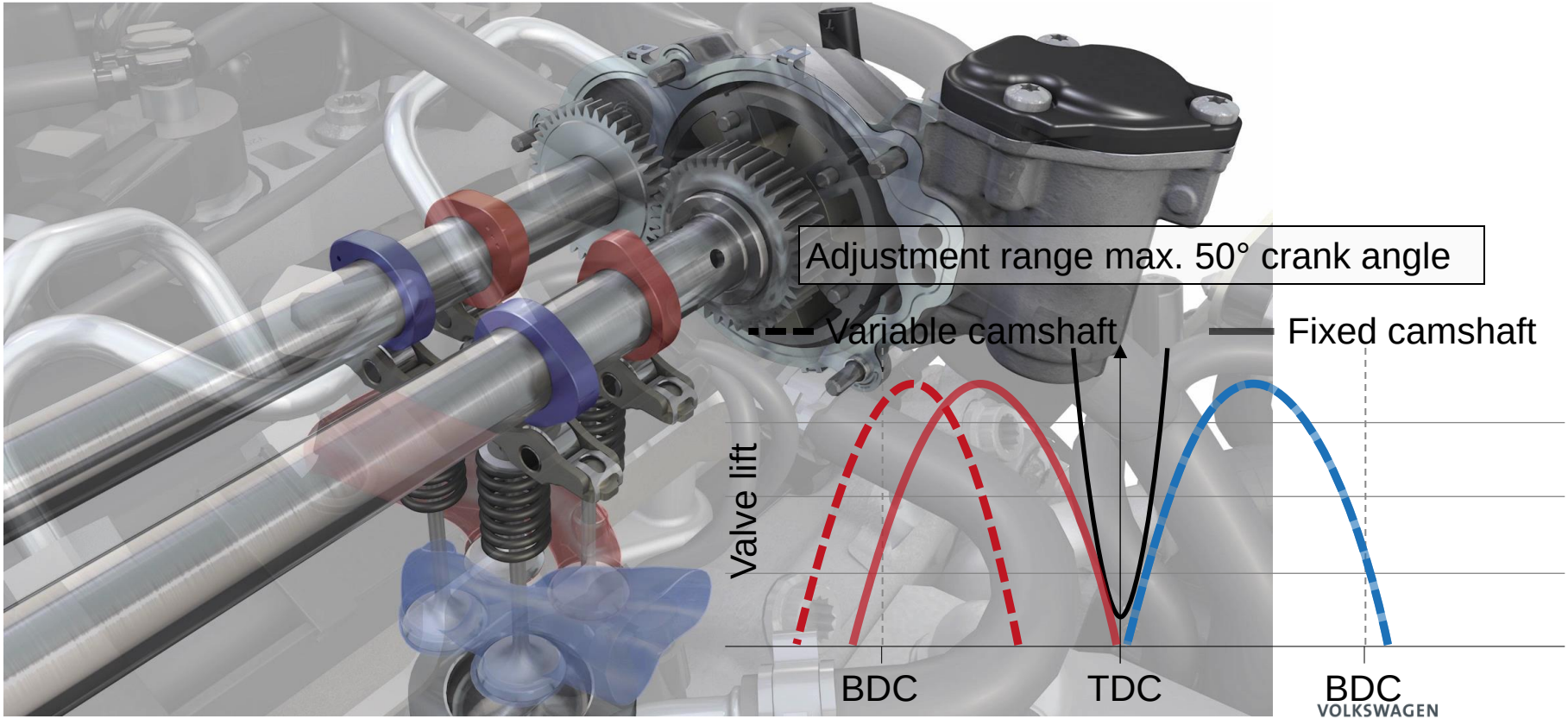
- Close-coupled NO_x aftertreatment

DUAL-CIRCUIT EXHAUST GAS RECIRCULATION - COMPONENTS

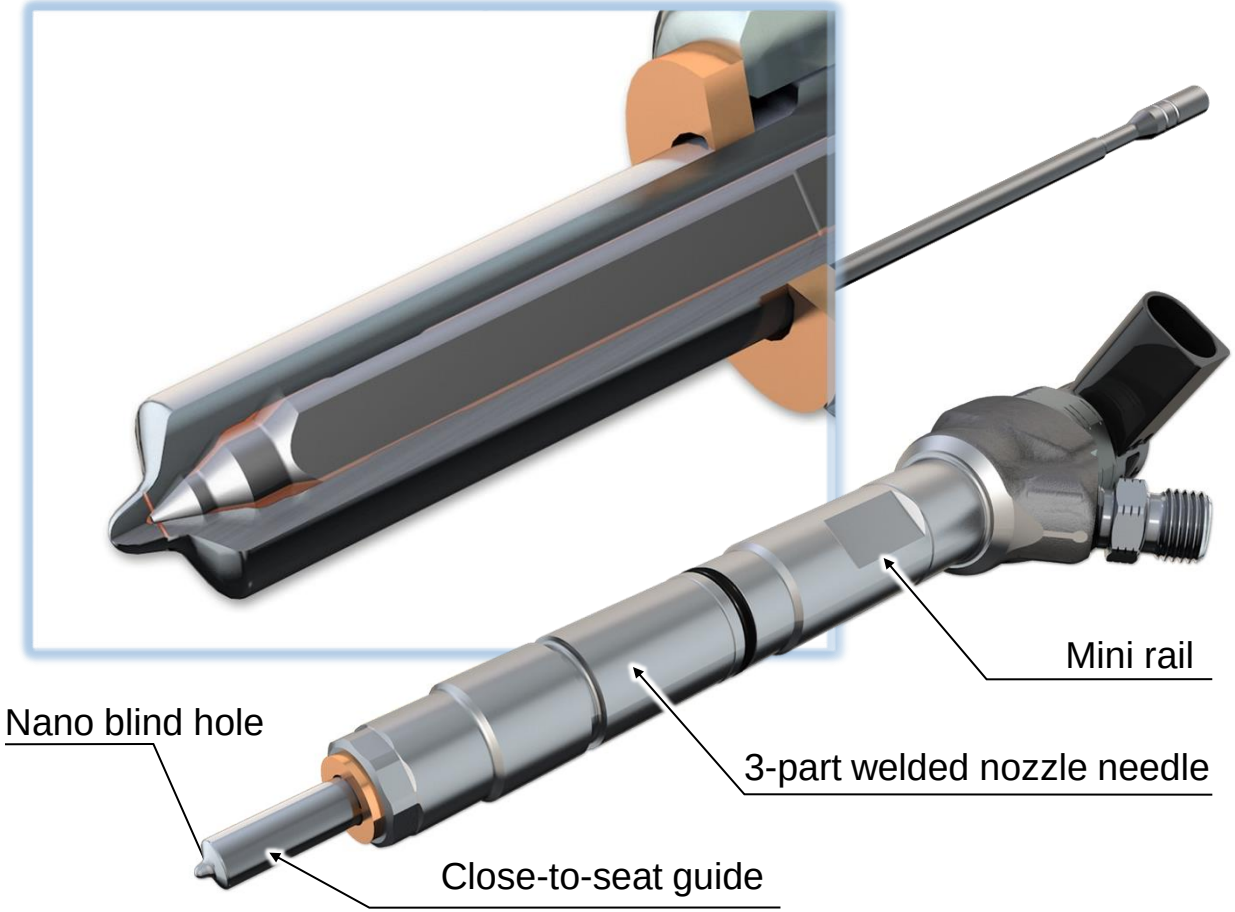


VVT CONCEPT – PORTS AND VALVES IN ROTATED POSITION

VVT OPERATING MODE - VALVE TIMING



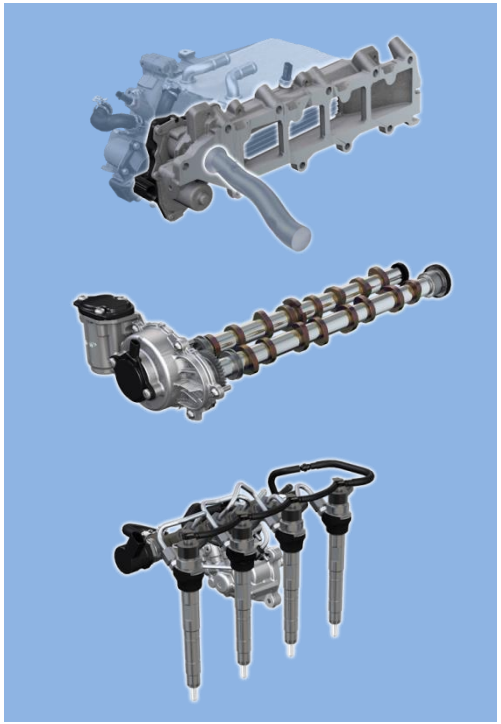
HIGH-PRESSURE INJECTION SYSTEM - INJECTOR



- Max. injection pressure 2000 bar
- Mini rail
- 3-part welded nozzle needle with close-to-seat guide
- Nano blind hole

THE MODULES OF THE TIER 3 EA-288 ENGINE

Modules basic engine

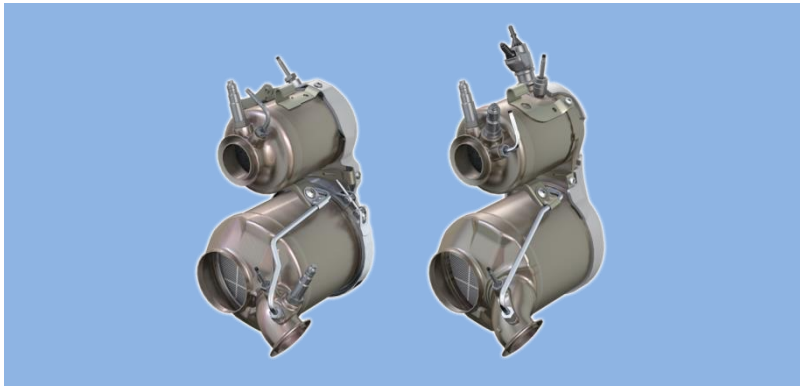


NOx

raw emissions

- 40%

Modules exhaust gas aftertreatment



Scaleable emissions aftertreatment for various levels up to **EU 6.2** and **LEV III/ Tier 3**

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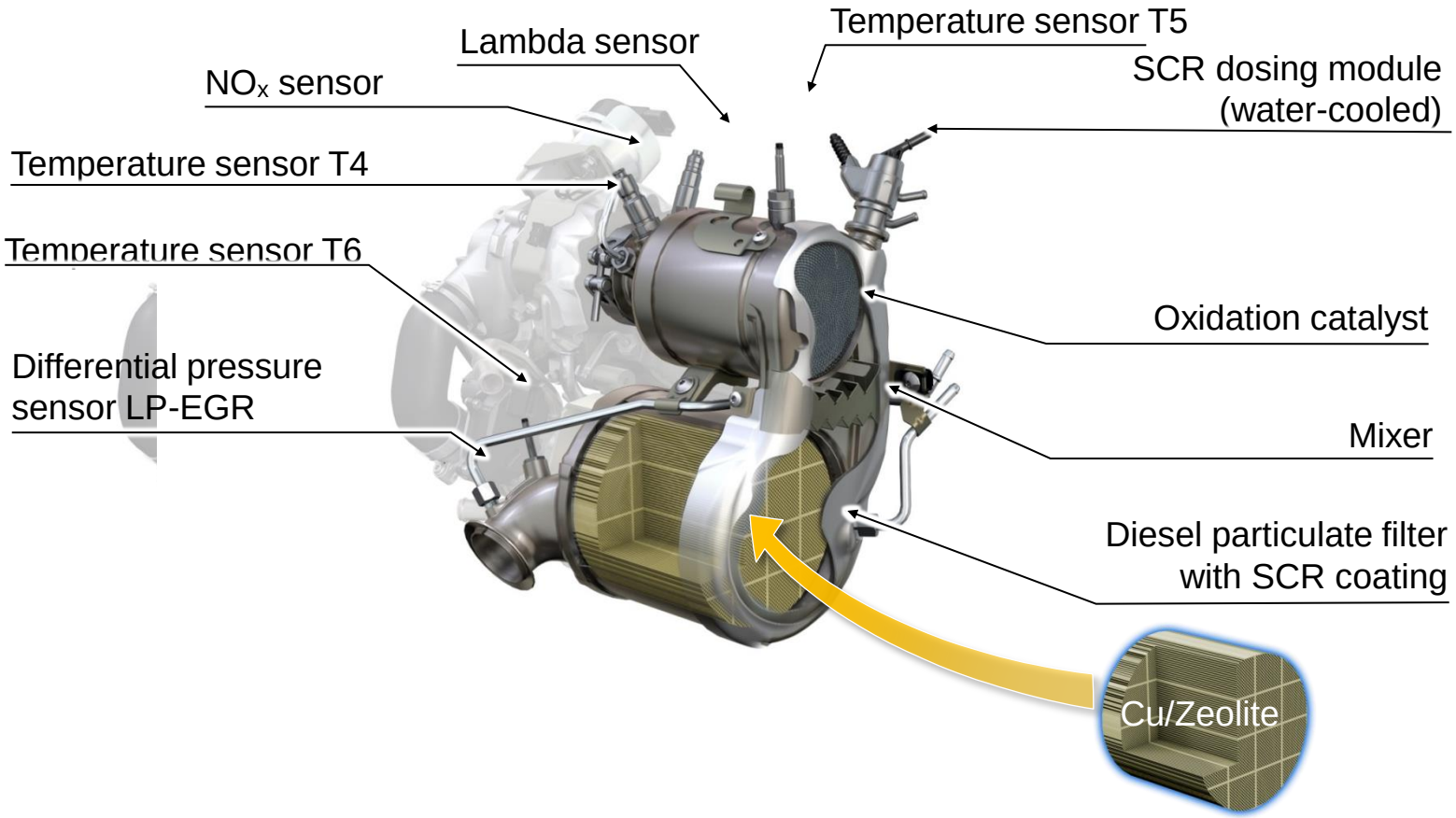
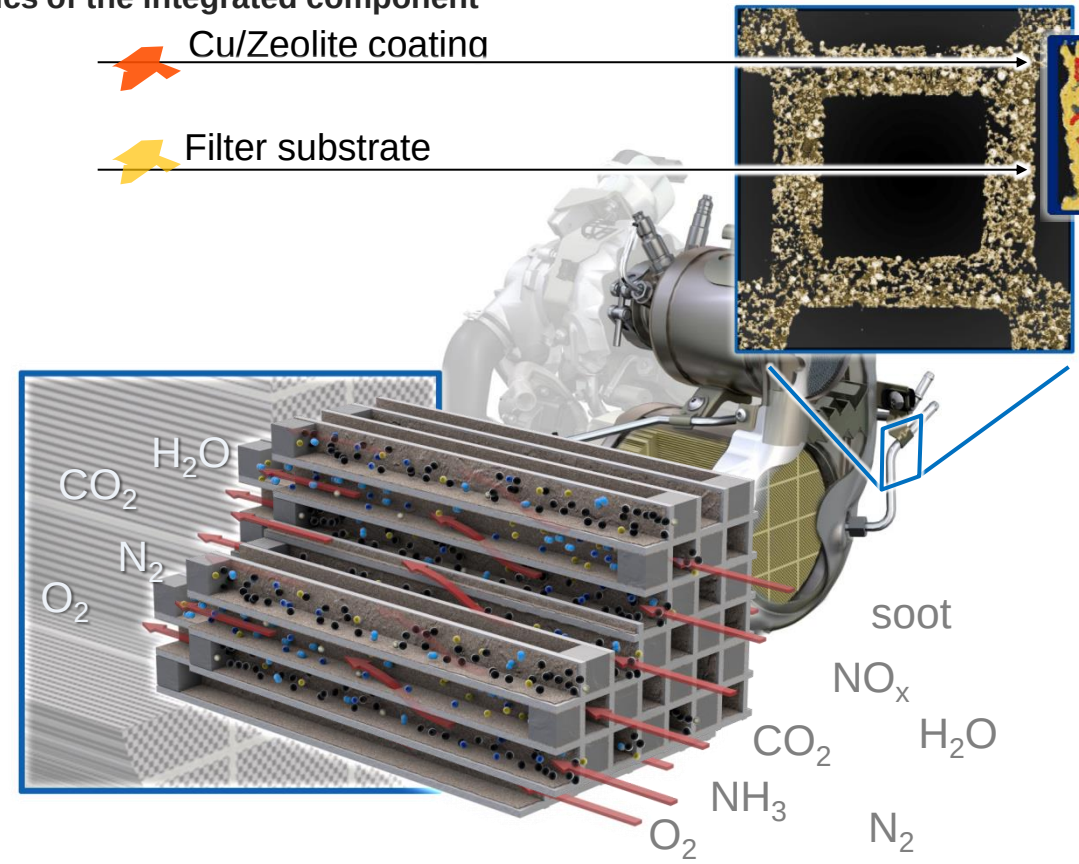
CLOSE COUPLED EXHAUST GAS AFTERTREATMENT

Tier 3 exhaust system design with Selective Catalytic Reduction (SCR)



DIESEL PARTICULATE FILTER WITH SCR COATING

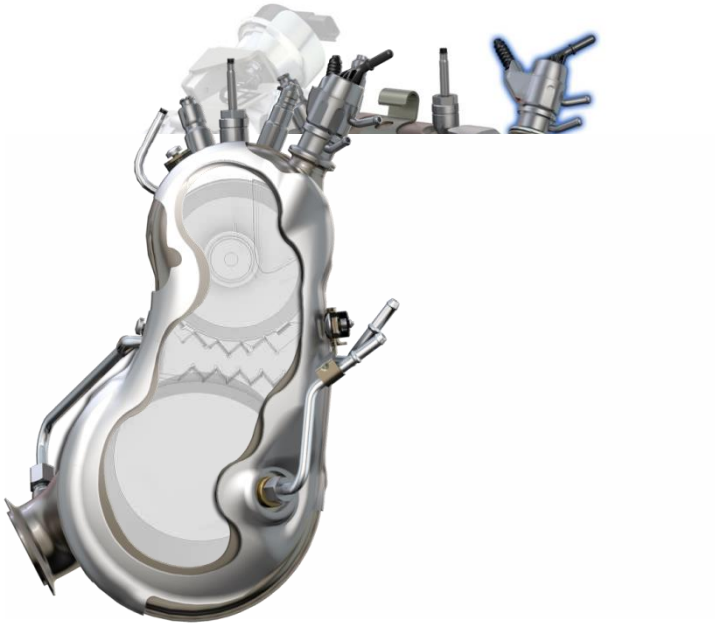
Characteristics of the integrated component



- DPF with optimized porosity
- High SCR washcoat amounts
- Thermally stable SCR coating
- Low exhaust back pressure and high filtration efficiency

DIESEL PARTICULATE FILTER WITH SCR COATING

Development of mixture preparation



- Mixture preparation in transfer tunnel
- Low exhaust back pressure with uniform NH_3 distribution
- Avoiding urea deposits

ENGINE TECHNOLOGY SUMMARY

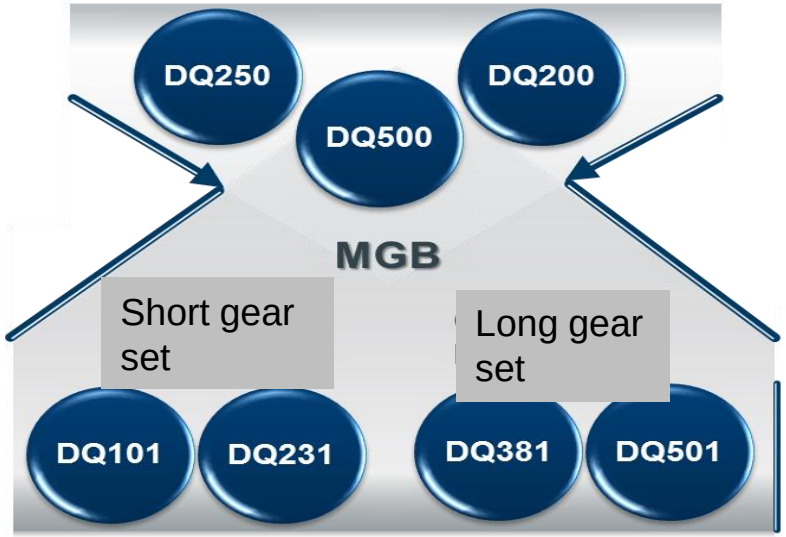
VW Group is converging towards three 4-cyclinder concepts as our volume leaders

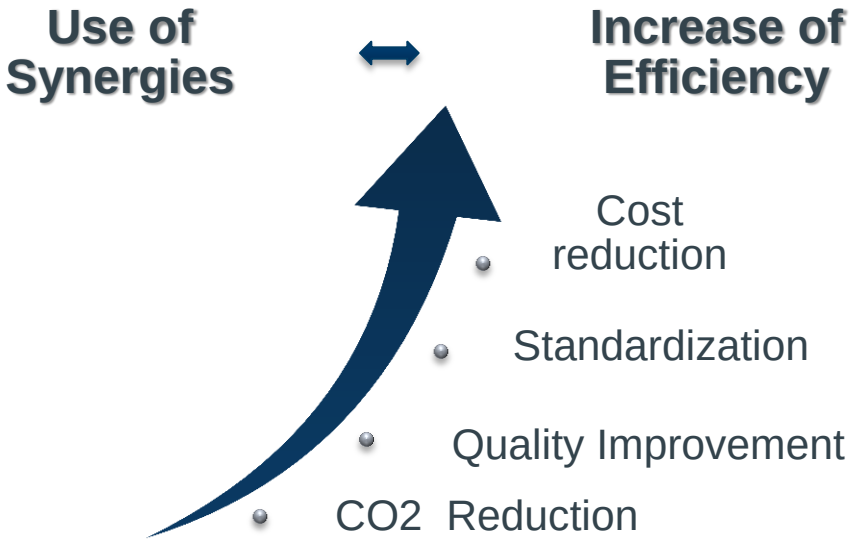
- EA888, EA211, and EA288 will comprise 95% of volume in the coming years
- Modular design of engines will permit use in multiple markets while meeting local cost targets

New engine technologies are focusing on:

- Reduced weight – up to 30% reduction
- Improvements in friction, and warm-up strategies
- Advanced, cost-effective valve trains
- Advanced turbo-charging with integrated cooling and faster response
- Optimized fuel injection
- Optimized combustion
- Reduced engine out emissions – emissions compliant in all markets
- Reduced CO2 emissions – 10 to 20%

GEARBOX TECHNOLOGIES – CONTINUED DSG DEVELOPMENT





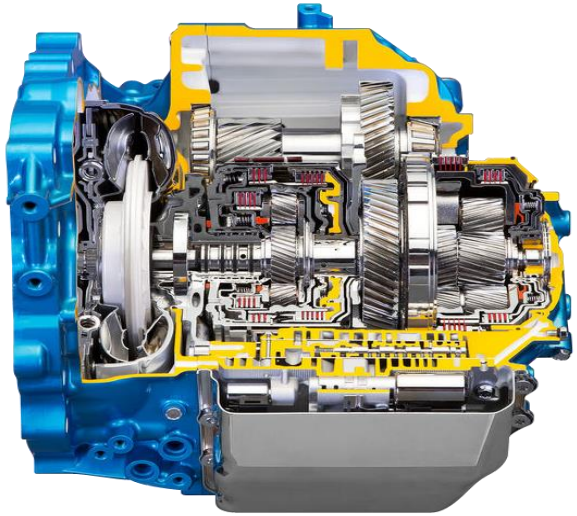
GEARBOX TECHNOLOGY: TRANSVERSE AT ≥ 8 Gears, Market NAR

Concept Guidelines:

- Successor of 6-speed AQ450-6F/A
- For US market cars Tiguan, B-SUV und CC NF
- Optimized efficiency
- Optimized NVH
- For Gasoline and Diesel Engines
- Torque range from 280 to 500 Nm

GEARBOX TECHNOLOGY: TRANSVERSE AT ≥ 8 Gears, NAR Market

Specification:

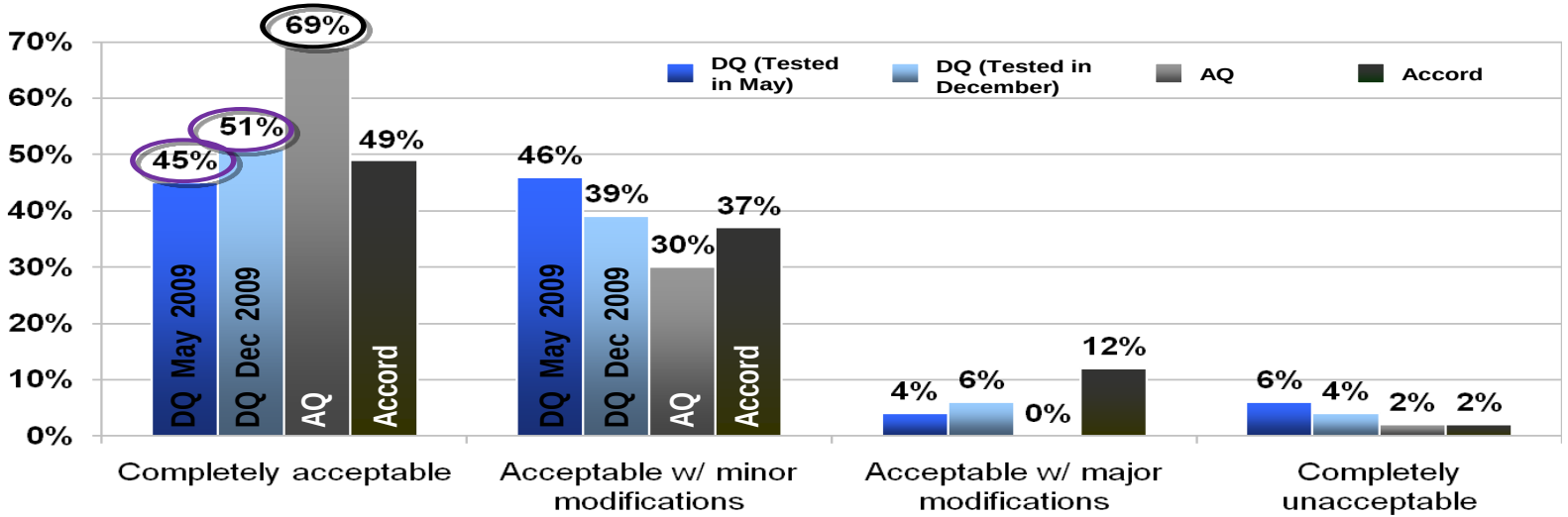


	Aisin AQ 450-8F/A
Gears	8
Spread	7,8 | 8,3
Final drive ratios	3,33 – 2,561
Max. power	220 kW
Torque capacity	500Nm | 360Nm
Weight	95 kg
Source	Aisin AW
Expected efficiency improvement	5 - 8 g CO2

GEARBOX TECHNOLOGY: CONSUMER ACCEPTANCE

- DQ200 updates produced **incremental improvements** to overall acceptability: "completely acceptable" scores increase (not significantly) by 6% (from 45% to 51%)
- **However, AQ is preferred to DQ200 by U.S. customers (69% "completely acceptable")**

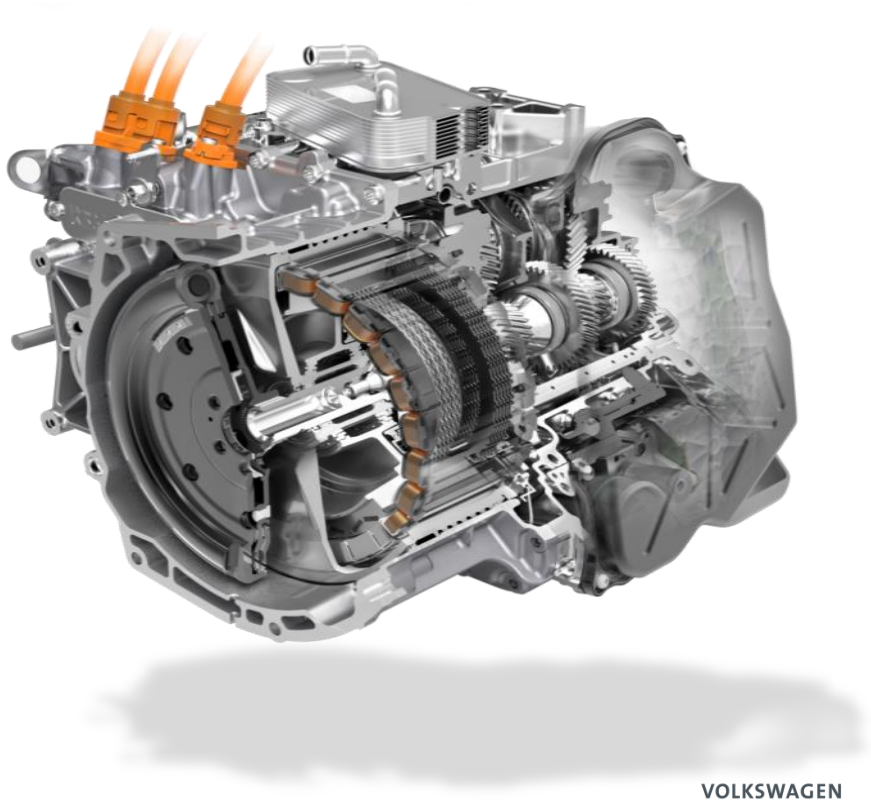
*How **acceptable** would this **transmission** be in a vehicle you would **consider purchasing**?*



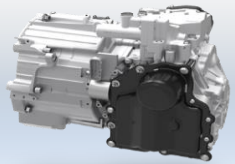
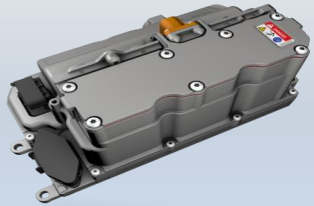
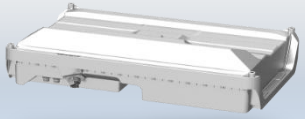
GEARBOX TECHNOLOGY: DQ400E PHEV TRANSMISSION

Specifications:

- Torque capacity : 400 Nm
- max. ICE-Torque : 350 Nm
- Integrated E-motor and clutch K0
- Oil supply on demand
- 2 circuit hydraulic control
  (High- / Low pressure)
- Friction optimized
- High efficient synchronizer system
- 6 forward gears



ELECTRIFICATION – VW GROUP HYBRID TOOLBOX

Engine	Electric motor	Gearbox	Battery	Power electronics
 2-cylinder in-line TDI	 HEM 20	 DQ200E	 HEV	 Power electronics
 3-cylinder in-line TSI/TDI	 HEM 60	 DQ400E	 PHEV	
 4-cylinder in-line TSI/TDI	 HEM 80			

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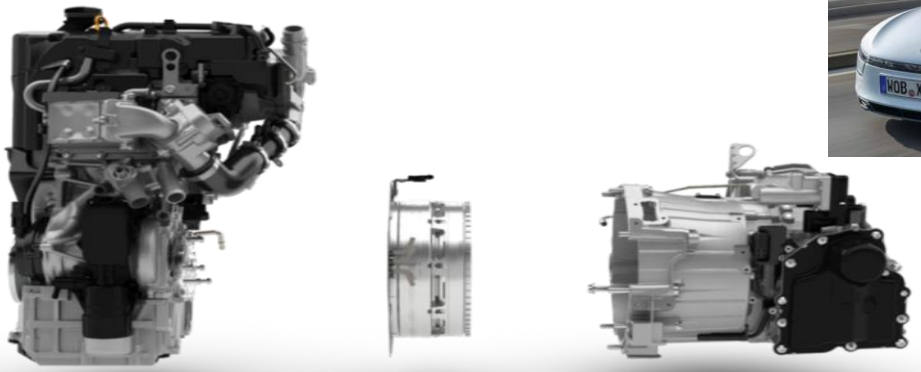
ELECTRIFICATION – VW XL1 HYBRID DRIVETRAIN



TDI engine

Displacement	830 cm³
Output/at rpm	35 kW/ 4,000 rpm
Torque/rpm	120 Nm/ 2,000 rpm
Weight:	72 kg

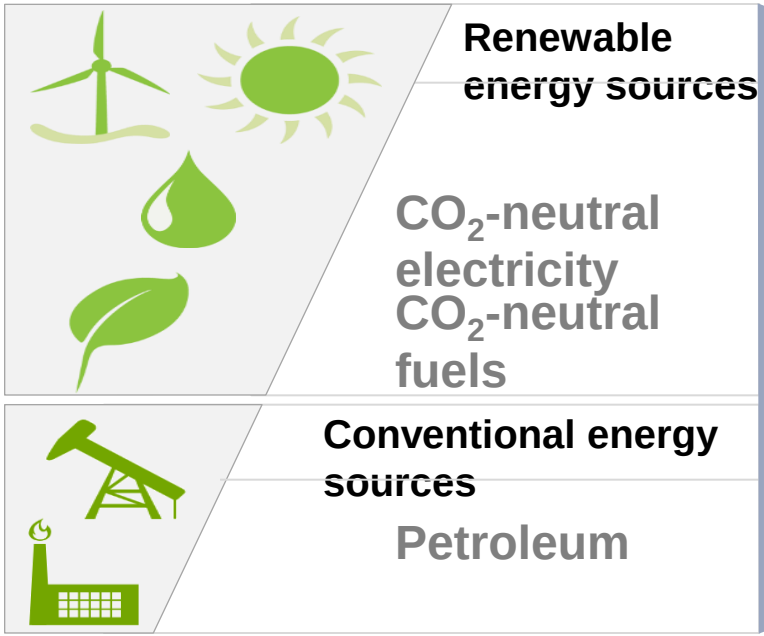
Electric motor

Type	Synchronous, permanent magnet
Output	20 kW
Torque	140 Nm
Weight	30 kg

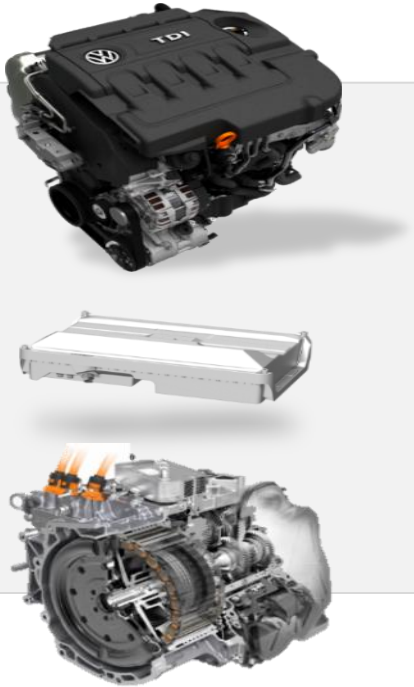
DSG gearbox

7 forward gears
Dry clutch
Magnesium casing

VOLKSWAGEN'S APPROACH TO SUSTAINABLE MOBILITY



TSI
TDI
TGI
DSG
TWIN DRIVE
BLUEMOTION
g-tron
e-tron
e-hybrid



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ALTERNATIVE FUEL DEVELOPMENT

	2013	2014
Hybrid vehicle (PHEV)	 Volkswagen XL1  Porsche 918 Spyder  Porsche Panamera S E-Hybrid	 Audi A3 e-tron  Volkswagen Golf TwinDrive
Battery vehicle (BEV)	 Volkswagen e-up!	 Volkswagen e-Golf
Compressed Natural Gas	 Audi A3 g-tron  Volkswagen Golf TGI	 SEAT León TGI  ŠKODA Octavia Sedan  ŠKODA Octavia Combi  SEAT León ST
Ethanol	 Volkswagen Saveiro  Volkswagen Golf Rallye  Volkswagen Fox Bluemotion	 Volkswagen up!  Volkswagen CrossFox  Volkswagen SpaceFox

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SUMMARY

- Tier 3/LEV 3 regulations, combined with the GHG/CAFÉ regulation, will drive many changes to powertrains
- Engine downsizing and down speeding will occur
- Four cylinder gasoline engines will dominate the market and must achieve Bin 20 and Bin 30 performance
- Six cylinder engines must also achieve Bin 30 emissions performance
- Larger engines and diesels must ultimately achieve Bin 50 and 70 performance when the regulations are fully phased-in
- Engine development will be focused on optimized combustion, fuel injection systems, variable valve timing, downsizing and charging
- Transmission technology will continue to evolve
- Increased hybridization of all types and in all market segments
- Continued controversy around PM standards and PM measurement

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