GHG Reducing Advancements and Technologies

CARB ACC Symposium

Diamond Bar, CA, September 28th, 2016
Dr. Dean Tomazic, Executive VP & CTO, FEV North America, Inc.

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Agenda

- **Introduction**
- **Development Trends**
- **Potential Game Changing Technologies**
- **Summary**

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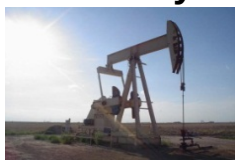
The Future of Powertrains
Current Global Situation

Global Mega Trends

Energy Security



Urbanization

Green Themes

Mass Mobilization

Resulting Drivers

Total Cost of Ownership

Legislation

Government Policies
(Taxation, Subsidies etc.)

Powertrain Technologies

ICE

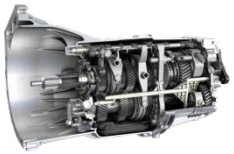
Natural Gas ICE

HEV

HHV

Fuel Cell

MT

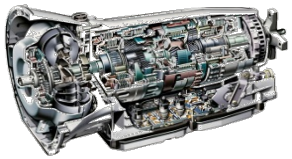


DCT

Hybrid

CVT

AT



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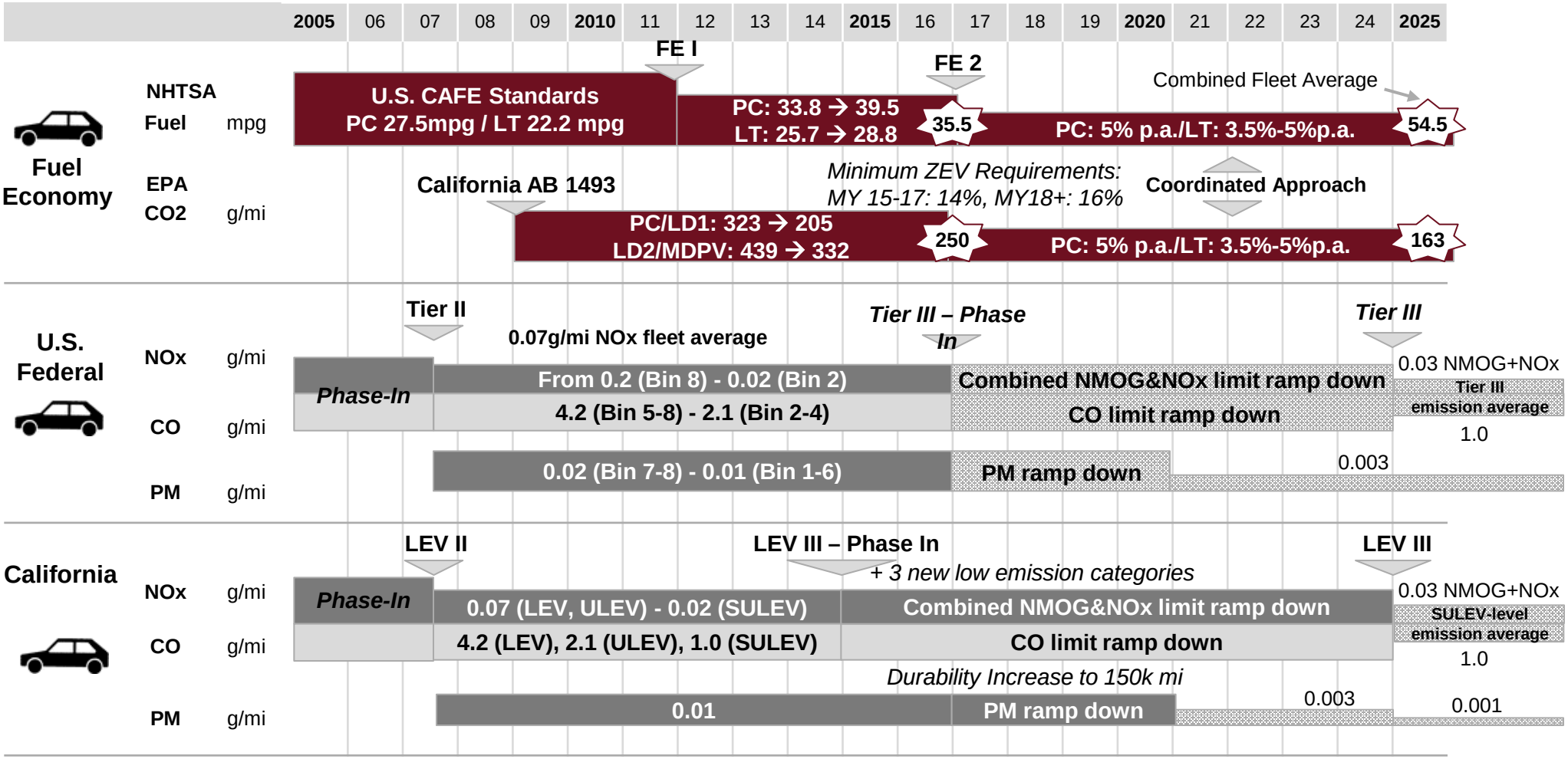
U.S. Emissions, Fuel Economy, and CO_2 Regulation Overview

U.S. – Passenger Cars and Light Trucks (GVW < 6,000lbs)



Source: Delphi, FEV Research

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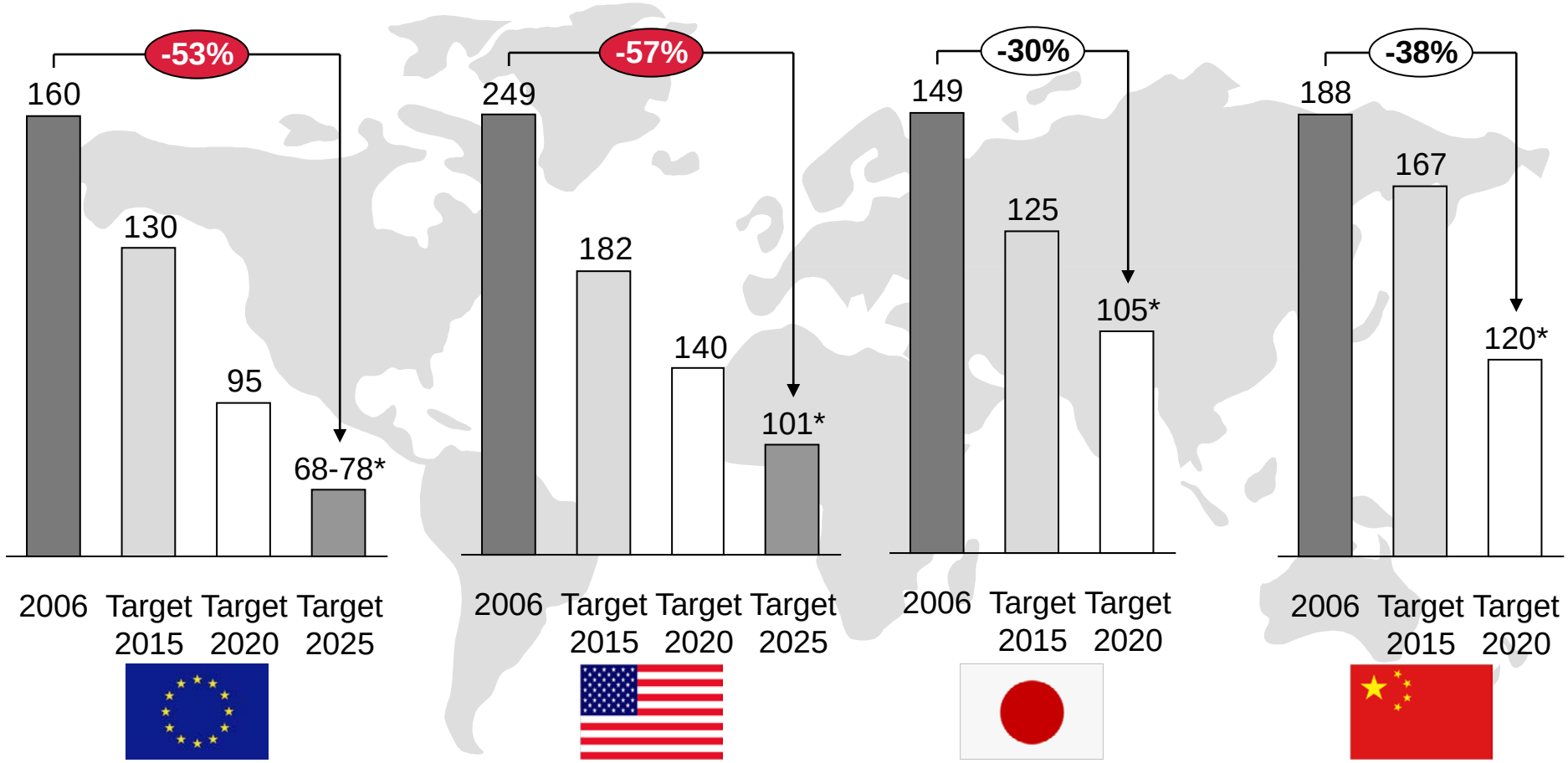
Development Trends
Global CO_2 Emission Targets

Worldwide regulations for CO_2 reduction – CO_2 fleet targets (g/km) NEDC based



* Proposed Target

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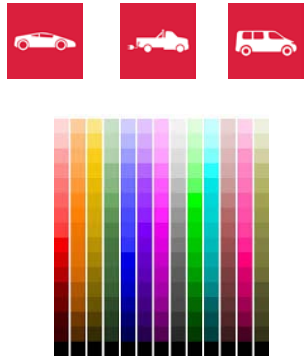
Development Trends
Consumer Expectations

Low Total Cost of Ownership (TCO)

- Vehicle purchase price / taxes
- Fuel economy (consumption)
- Maintenance/repair cost
- Residual value
- Etc.

Vehicle Appearance/Styling

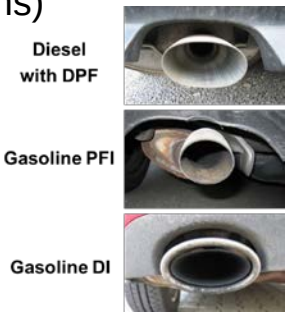
- Application driven
- Ergonomic design
- Sporty / Color
- Infotainment
- Etc.



Consumer

Environmentally Friendly

- High FE (low CO2 emissions)
- Low harmful emissions
- Recycle
- Etc.



Performance & NVH

- High power
- High low-end torque
- Quiet yet sporty
- Active & passive NVH measures
- Etc.

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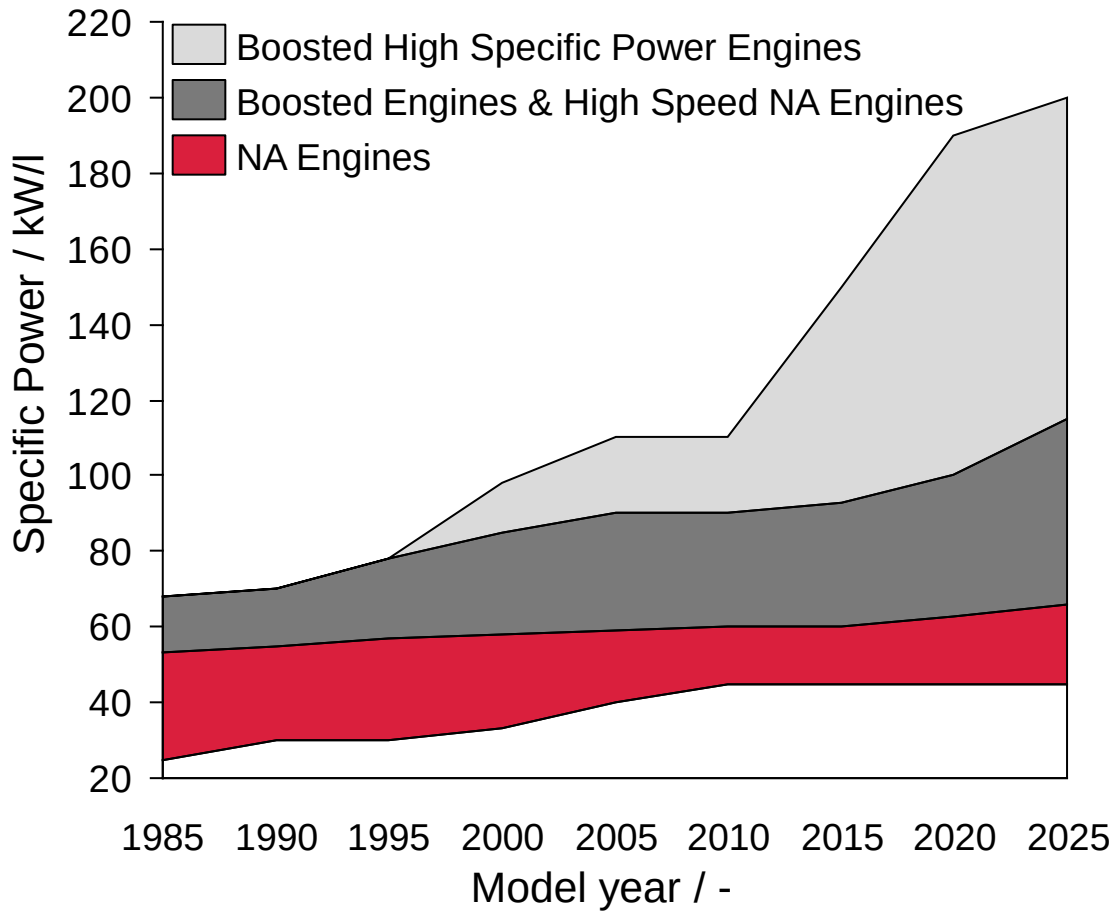
Development Trends
Gasoline Engines

Specific Power: History and Future



- Extrapolation of trend based on ongoing market survey
- Maximum specific power depends on market position of individual OEM
- Mainstream engine of Premium OEM might have higher BMEP than ‘high performance engine’ from large volume OEM
- Additional features for future considered, e.g. variable compression ratio (VCR)

Source: FEV Consulting

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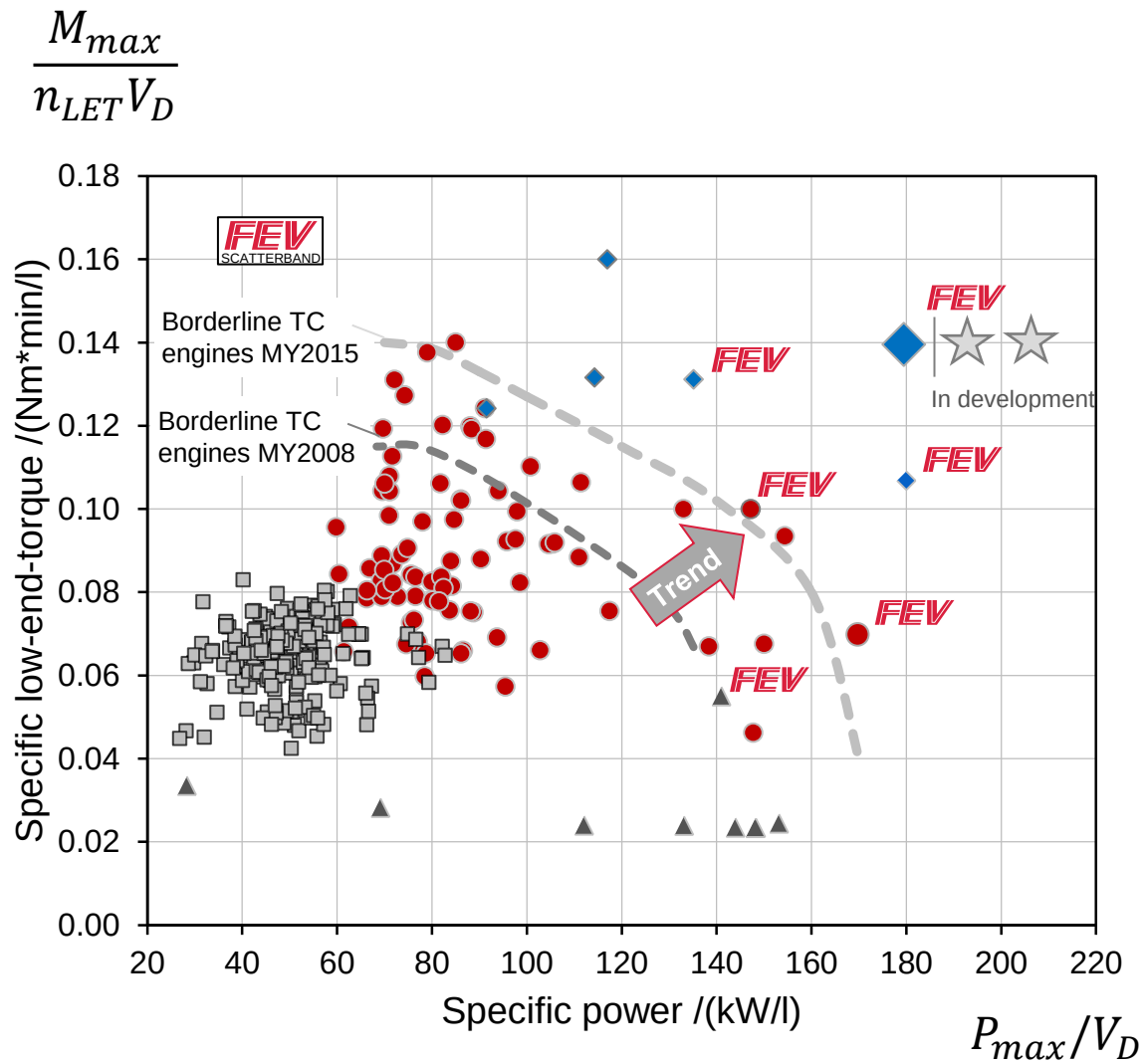
Development Trends
Gasoline Engines



- Trend:
  - Further downsizing
  - High specific power & LET
- Several high performance engines in development at FEV
- Boosting system is key component
- 1-stage boosting limited
- 2-stage boosting to combine high specific power and low-end-torque (LET):
  - TC + eC
  - TC + TC
  - TC + SC

NA engines | 1-stage boosted engines | 2-stage boosted engines | Motorcycle engines | FEV under development at FEV

Source: FEV

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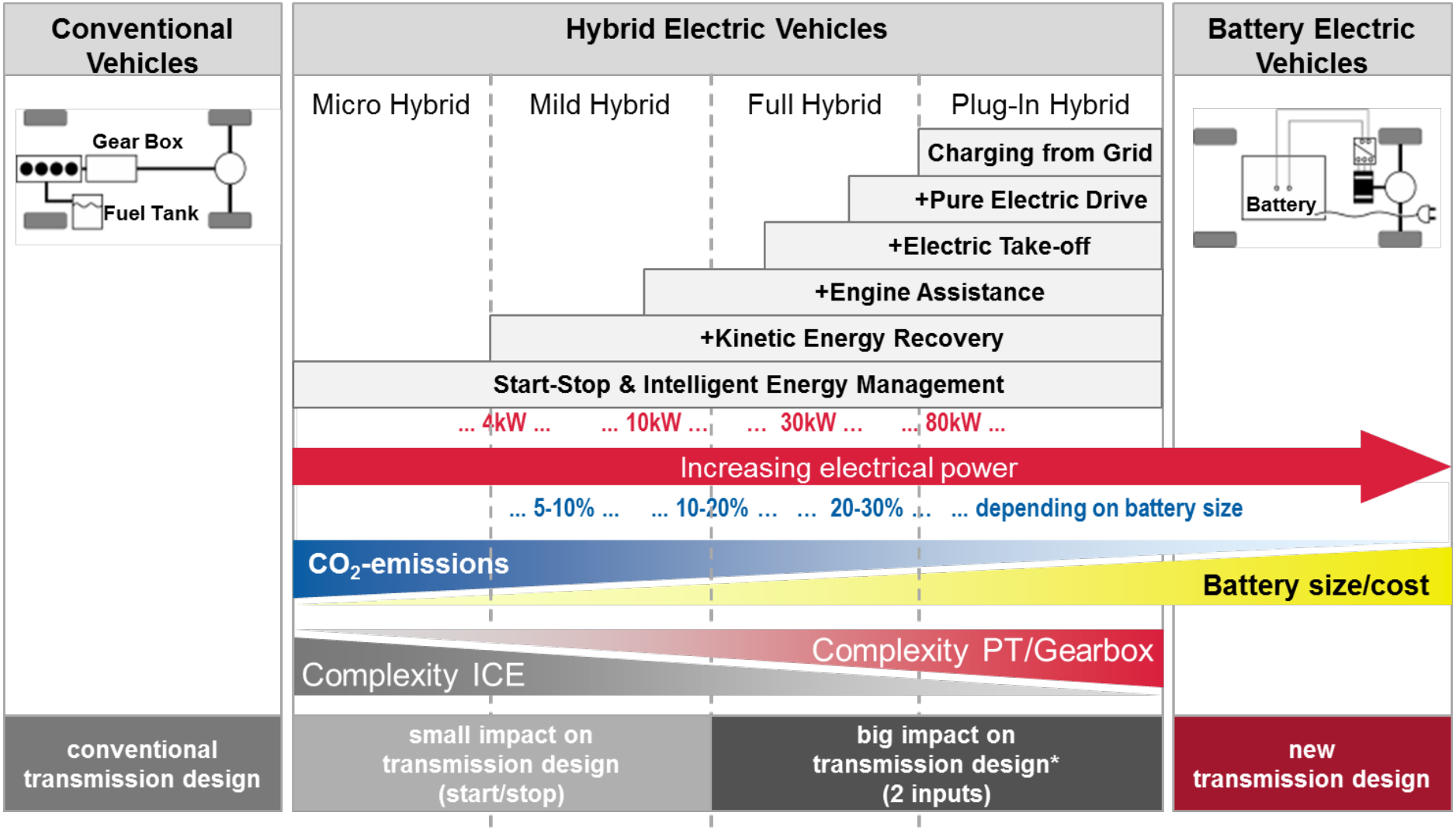
Technology Trends
Hybridization / Electrification / Transmissions



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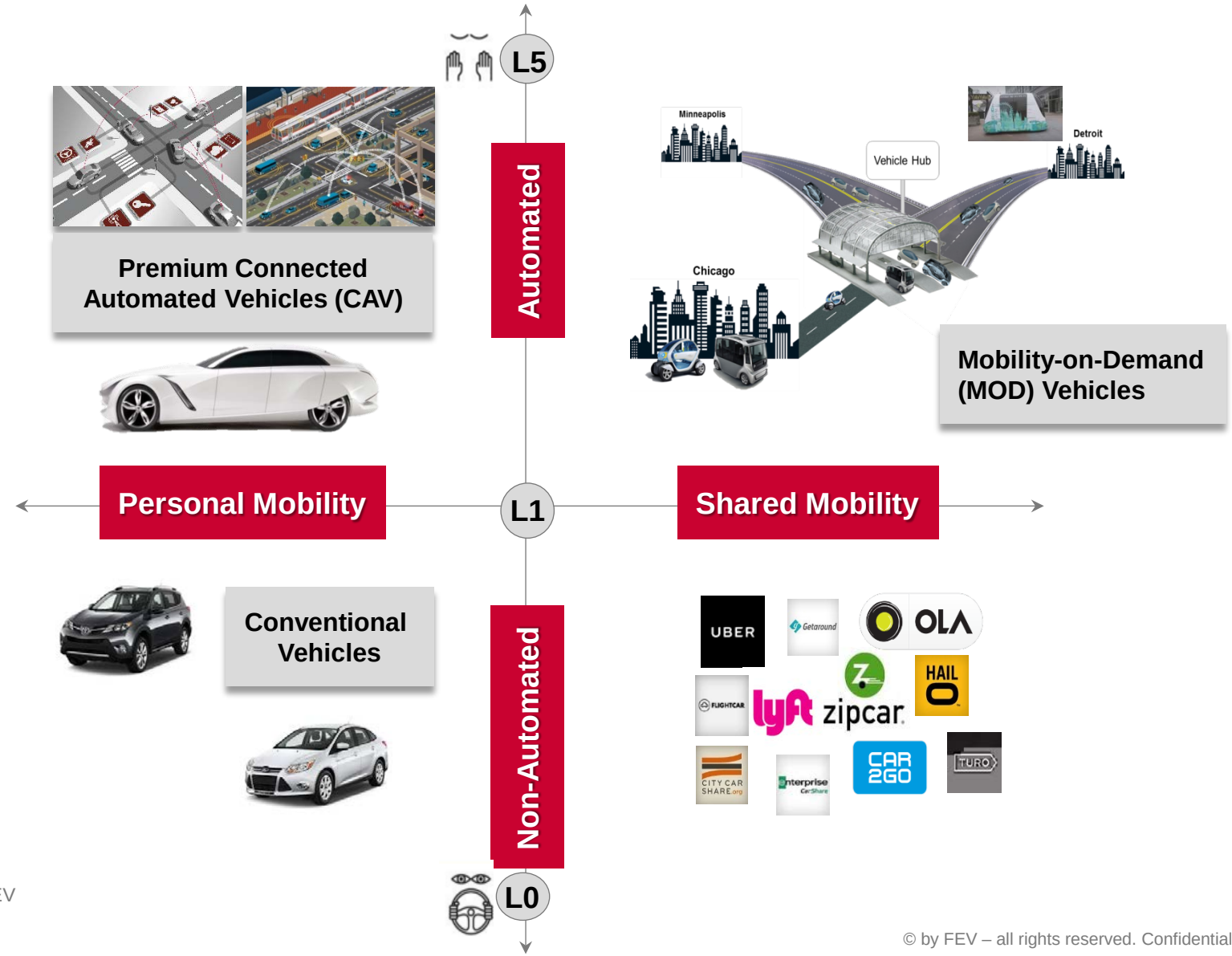
Technology Trends
Vehicle Landscape: Automation, Shared Mobility and Connectivity



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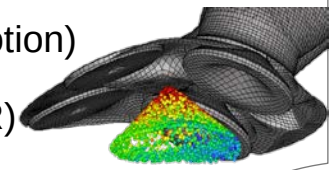
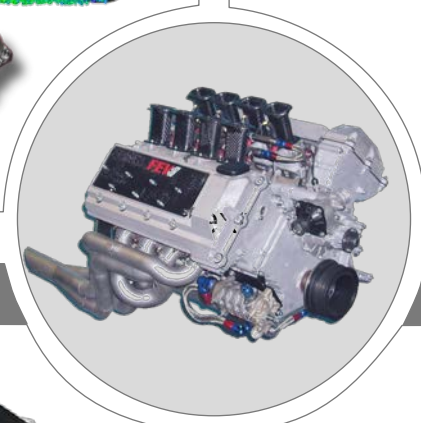
Development Trends
Gasoline Engines

Combustion Efficiency Improvements

- Direct Injection (& Var. Charge Motion)
- Variable Compression Ratio (VCR)
- Miller/Atkinson Cycle
- Cooled EGR
- Controlled Auto-Ignition (CAI)





Reduction of Throttling Losses

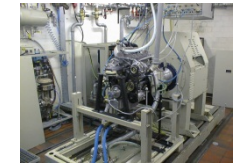
- Downsizing
- Boosting
- Cylinder Deactivation
- Variable Valvetrain
- Lean-burn Operation

Electrification/Hybridization

- Micro/Mild/Full Hybrid
- PHEV
- 48V Infrastructure
- Accessory (FEAD) Electrification

Reduction of Parasitic & Idle Losses

- Friction Reduction
- Stop/Start
- Advanced Thermal Management
- Accessory (FEAD) Electrification



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Development Trends
Gasoline Engines

Example:

Three-Cylinder GTDI

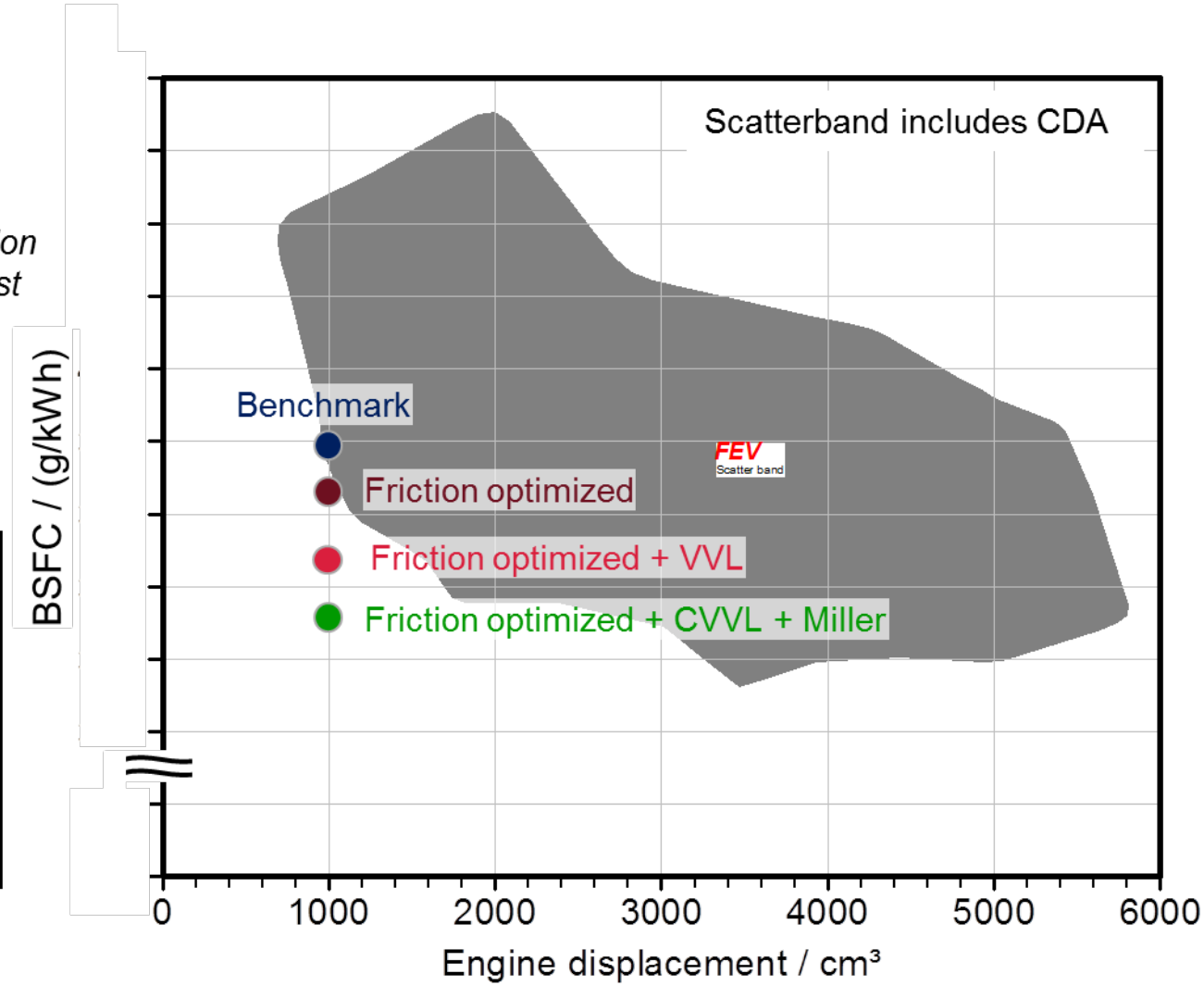
- *Best in class BSFC*
- *Variable valve lift*
- *Friction optimized*
- *State-of-the-art combustion*
- *Optimized air and exhaust management*

Brake Specific Fuel Consumption

norm. to calor. val.=42.5 MJ/kg

2000 rpm / BMEP = 2 bar

- SI engines
- Production state
- Model year > 1997



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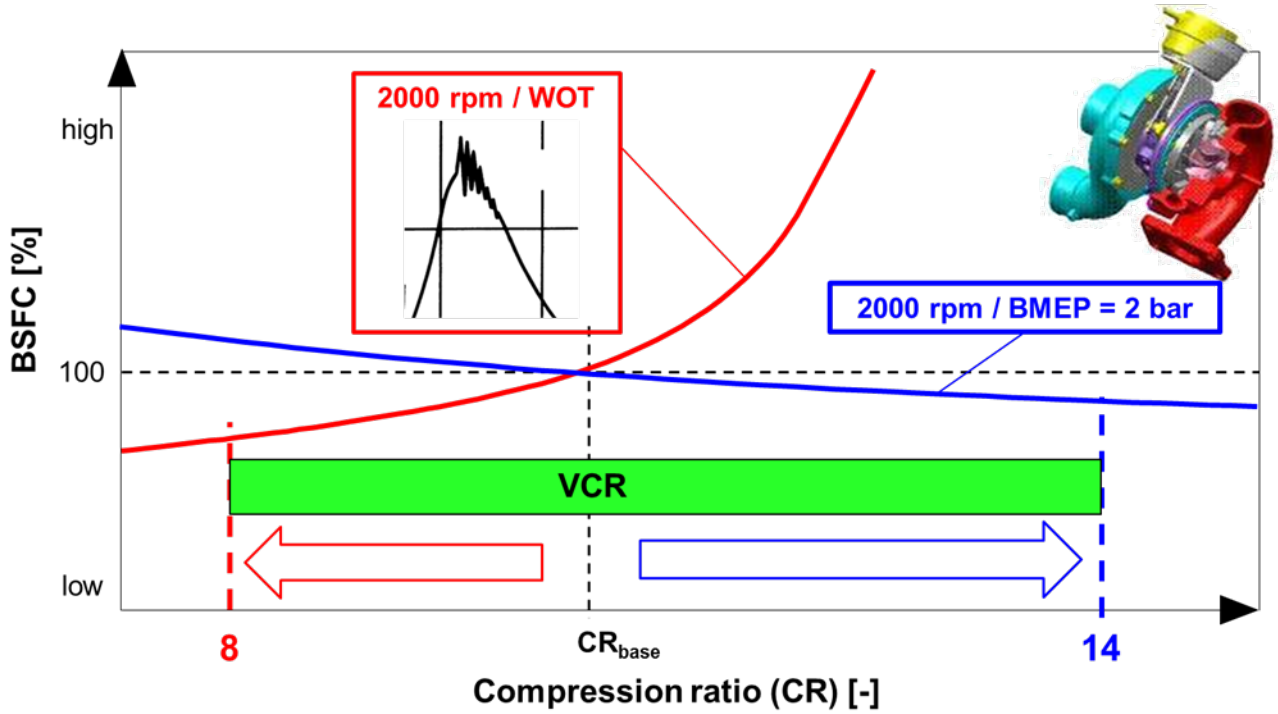
2-Step Variable Compression Ratio (VCR) Mechanism
Background & Incentive



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Key figures

- Conflict of aims:
  - High compression ratio for excellent part load efficiency
  - Low compression ratio for reduced knocking at high / full load
- This trade-off can be solved by systems allowing a variable compression ratio

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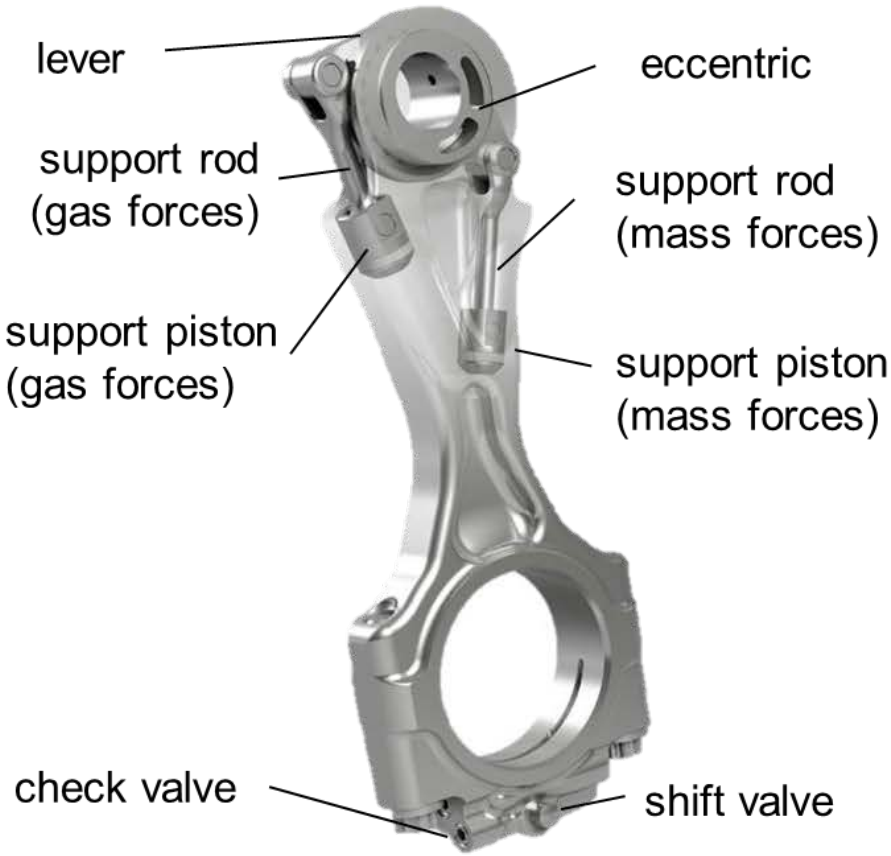
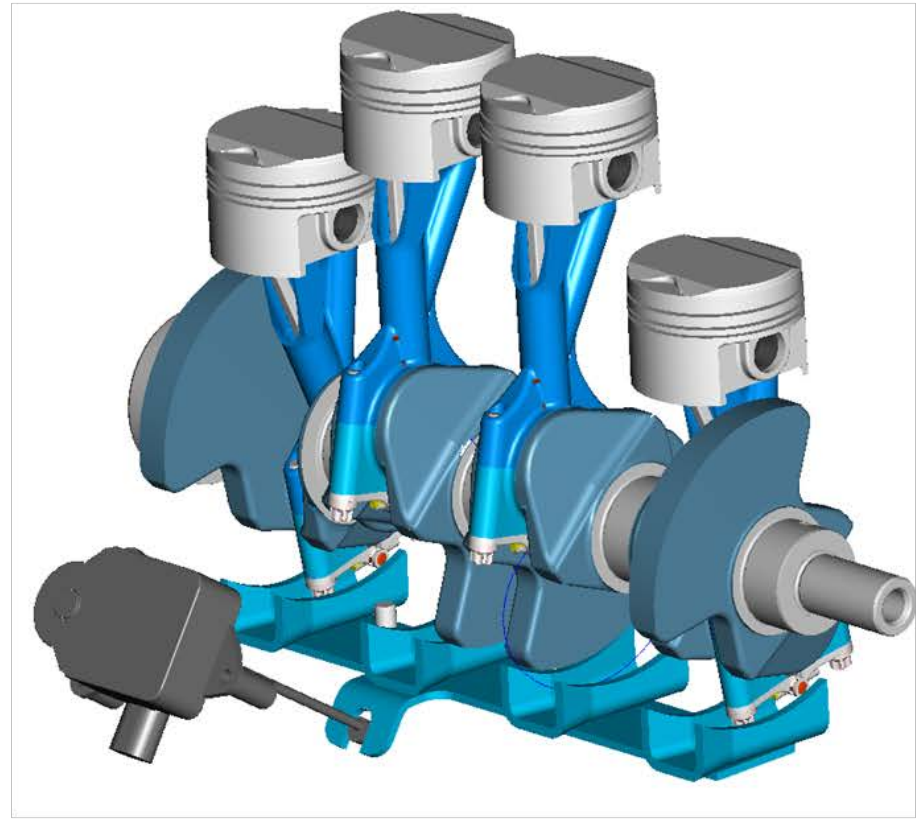
2-Step Variable Compression Ratio (VCR) Mechanism
Design Features

Connecting rod design



Mechanical actuation



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2-Step Variable Compression Ratio (VCR) Mechanism Functionality

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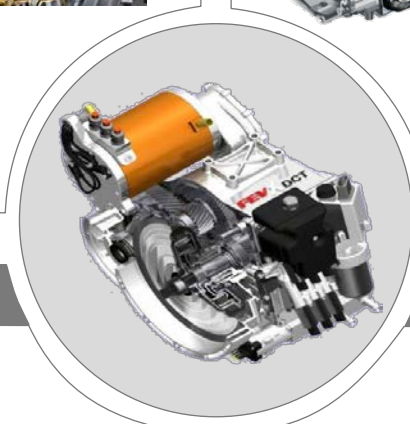
Development Trends
Transmissions

‘Direct’ Transmission Efficiency Improvements

- High Efficiency Oil Pumps
- Minimized Open Clutches
- Low-Loss Bearings/Seals/Gears
- Low-Leakage Hydraulics
- Low-Viscosity Oils

‘Indirect’ Transmission Efficiency Improvements

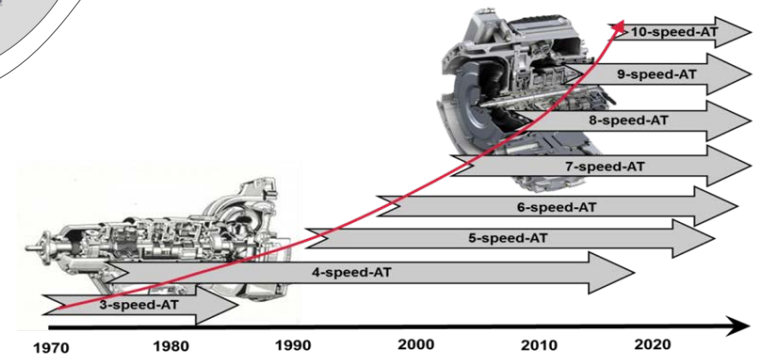
- Increased Number of Speeds
- Increased Ratio Spread
- Aggressive Torque Converter Lock-Up
- Active Thermal Management



Transmission Types

- Manual/AMT/DCT
- Planetary Automatics
- CVT
- Hybrids

Development Path



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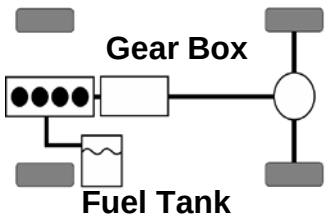
Hybridization
Architectural Alternatives

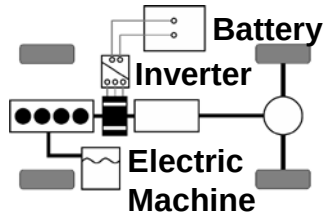
Increasing Degree of Hybridization/Electrification

Conventional ICE-Only Vehicle

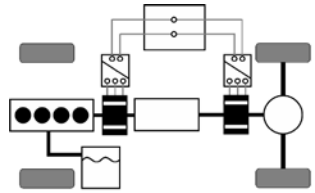


Hybrid Electric Vehicle (HEV)

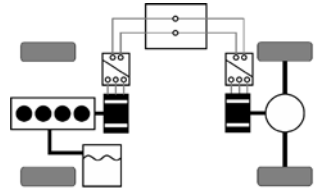
Parallel-Hybrid



Power Split-Hybrid

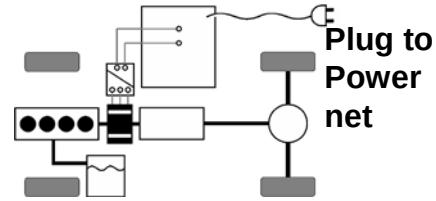


Series-Hybrid

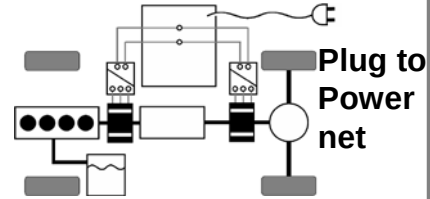


Plug-In (PHEV)

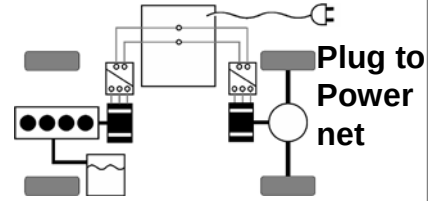
Parallel-Hybrid



Power Split-Hybrid

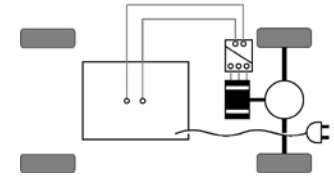


Series-Hybrid

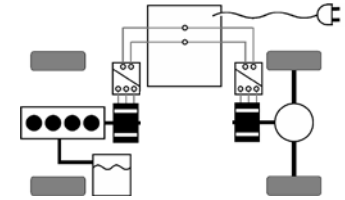


Battery EV (EV)

Electric Vehicle



BEV with REX



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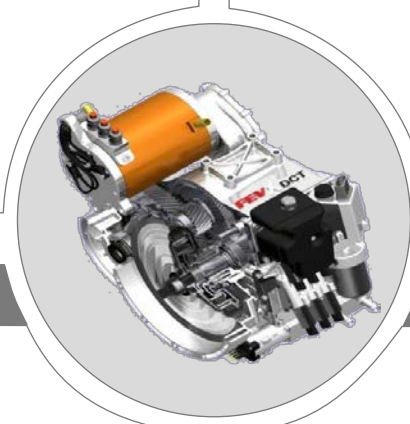
Development Trends
Fuels and Lubricants

Spark Ignition Engine Fuels

- Low octane fuels
- 10% Ethanol content
- LPG
- CNG
- Etc.

Diesel Engine Fuels

- Low cetane fuels
- Nationwide quality fluctuations
- Availability
- Cost disadvantage
- Etc.



Lubricants

- Low viscosity
- High temperature stability
- Additive packages
- ‘Fill for life’ (transmission & axles)
- Etc.

Other Potential Fuels

- Alcohols (Methanol, Ethanol, etc.)
- 2nd gen. biofuels
- Tailor-made fuels
- Biodiesel
- Etc.

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Summary

- **The industry is facing multidimensional challenges from a legislative, economic and societal perspective. Technical solutions must satisfy all of these requirements to succeed in the marketplace.**

- **Technologies to meet future requirements are either already available or under development. However, different markets have different requirements and hence different technical solutions.**

- **Due to these requirements, the variability of different powertrain types will continue to increase resulting in the need to also adapt fuels and lubes accordingly.**

- **A ‘one fits all’ solution becomes more and more unlikely due to the vast differences among the different powertrains and the way they will be used in the market.**

- **The main challenge remaining is to develop a cost efficient powertrain portfolio that meets legislative requirements and is accepted by the customer despite fluctuating fuel prices.**

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