Intersection of Powertrain Innovation for Improving Future Vehicle Fuel Efficiency and Connected Autonomous Vehicles

Powertrain Control and Optimization for Future Fuel Efficiency

Dr. Dean Tomazic
EVP & CTO
FEV North America Inc.

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Powertrain Control and Optimization for Future Fuel Efficiency
Agenda

1. *Introduction*
2. Potential of Powertrain Technologies
3. Potential of Vehicle Connectivity
4. Summary and Outlook
5. Discussion

Powertrain Control and Optimization for Future Fuel Efficiency
Key Drivers

Fuel Economy and CO_2 Emissions
Downsizing, Downspeeding, GTDI, Friction Reduction, Combustion Optimization, etc.

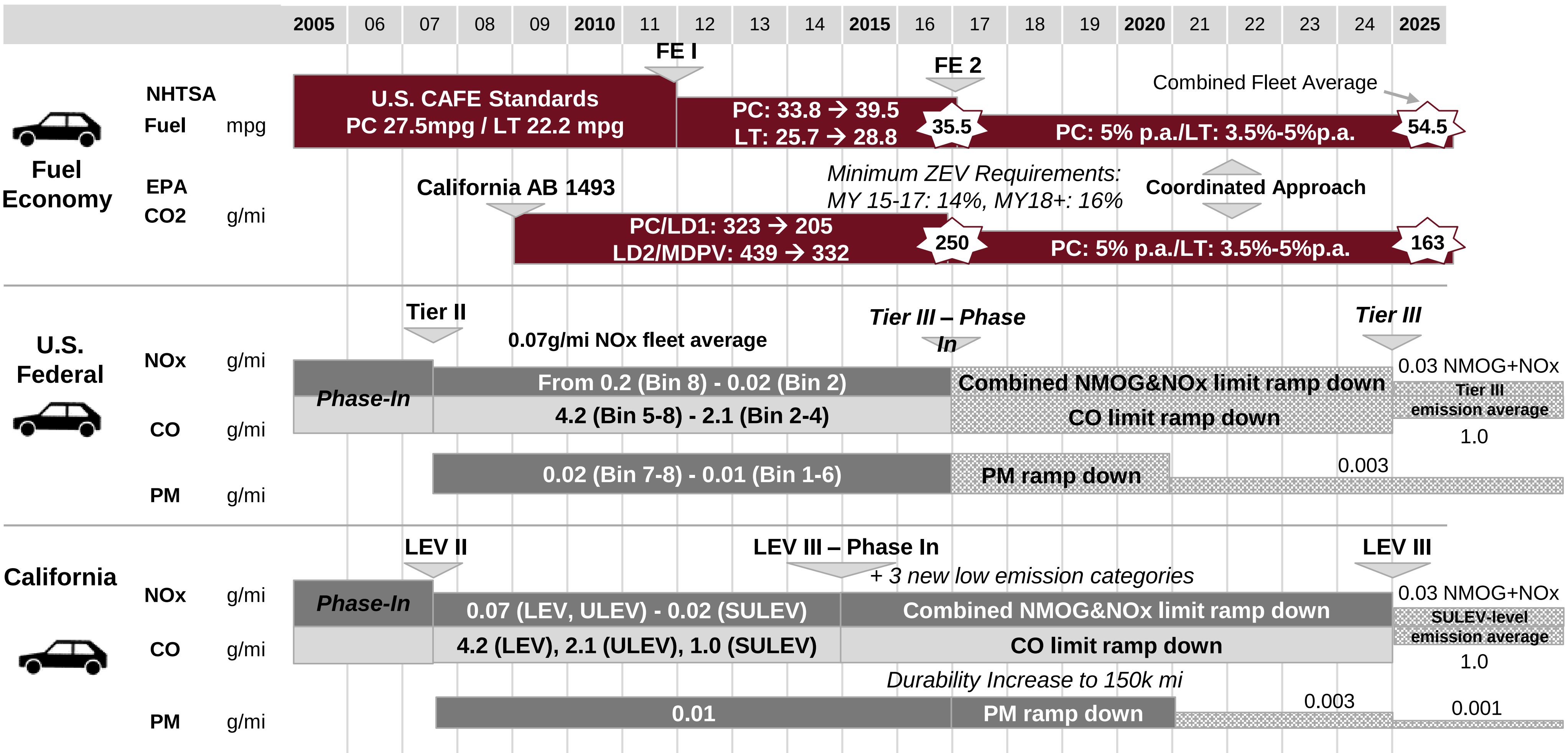
Emissions
SULEV Average w/ Stoichiometric and (Stratified) Lean-Burn Combustion Systems

Fuels
Increased Share of Biofuels (e.g., Ethanol (Corn, Algae, Cellulosic), Biodiesel, CNG, etc.)

Reliability and Affordability
TCO for Consumer

Powertrain Control and Optimization for Future Fuel Efficiency
U.S. Emissions, FE and CO_2 Legislation

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



Source: Delphi, FEV Research

Powertrain Control and Optimization for Future Fuel Efficiency
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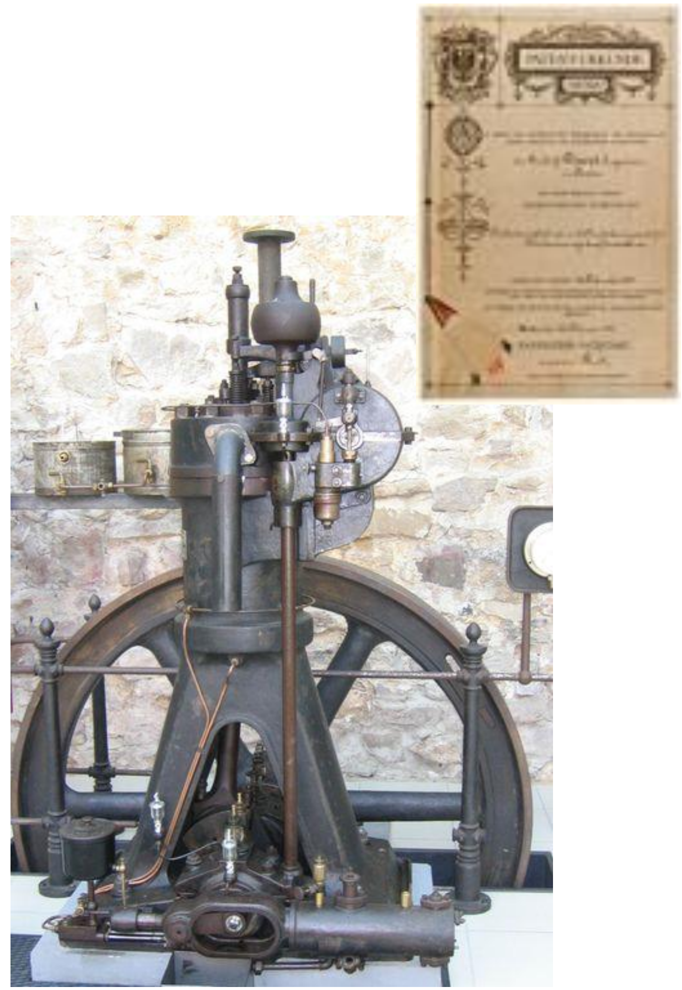


Powertrain Control and Optimization for Future Fuel Efficiency Development Trends – Gasoline Engines

Example:

Three-Cylinder GTDI

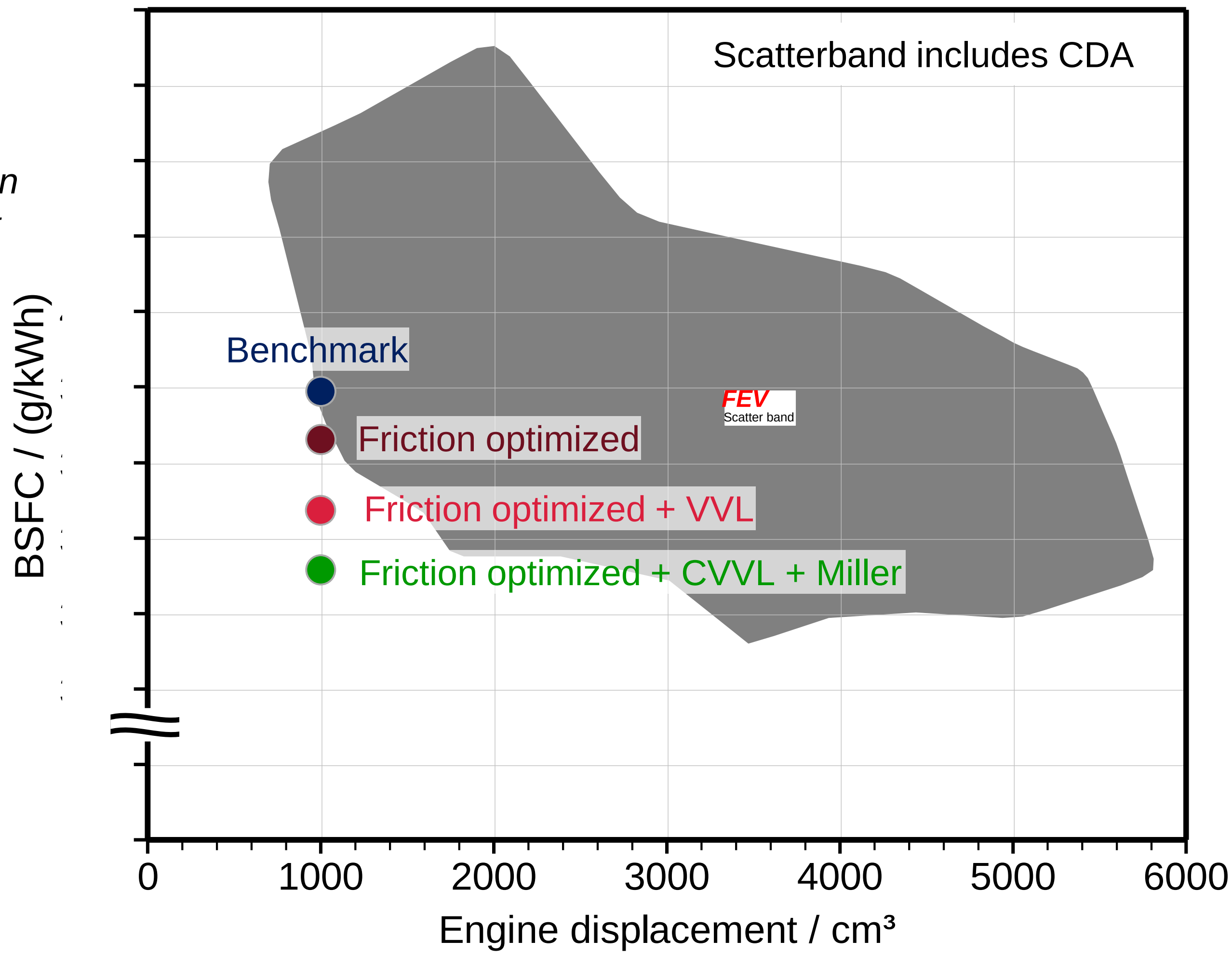
- *Best in class BSFC*
- *Variable valve lift*
- *Friction optimized*
- *State-of-the-art combustion*
- *Optimized air and exhaust management*

Brake Specific Fuel Consumption

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

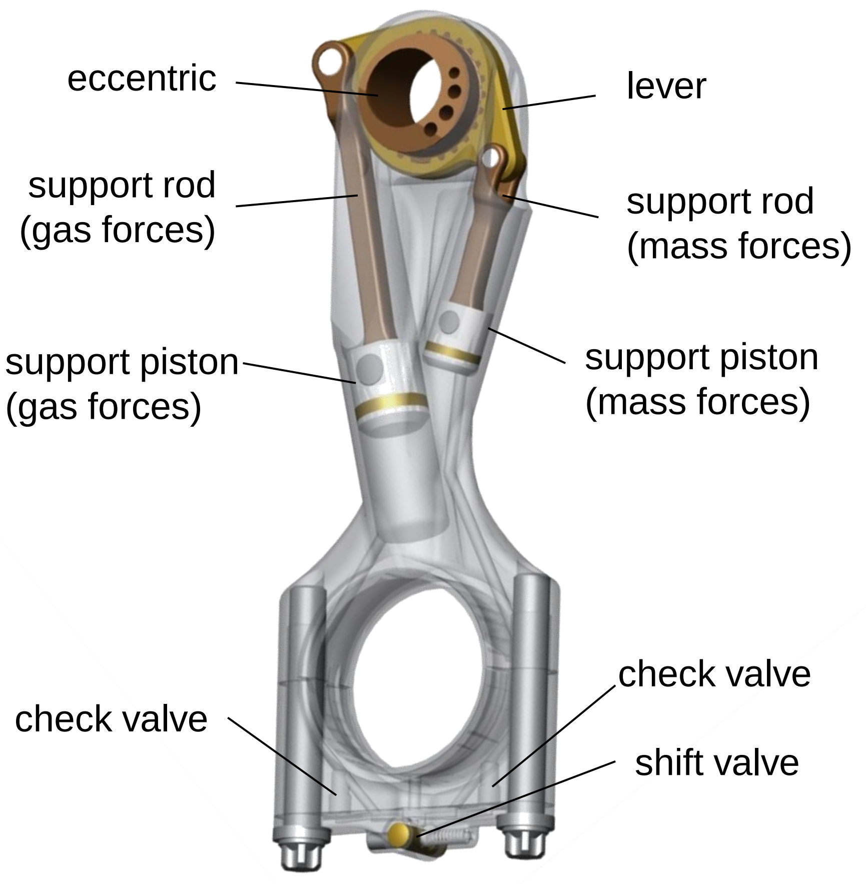
2000 rpm / BMEP = 2 bar

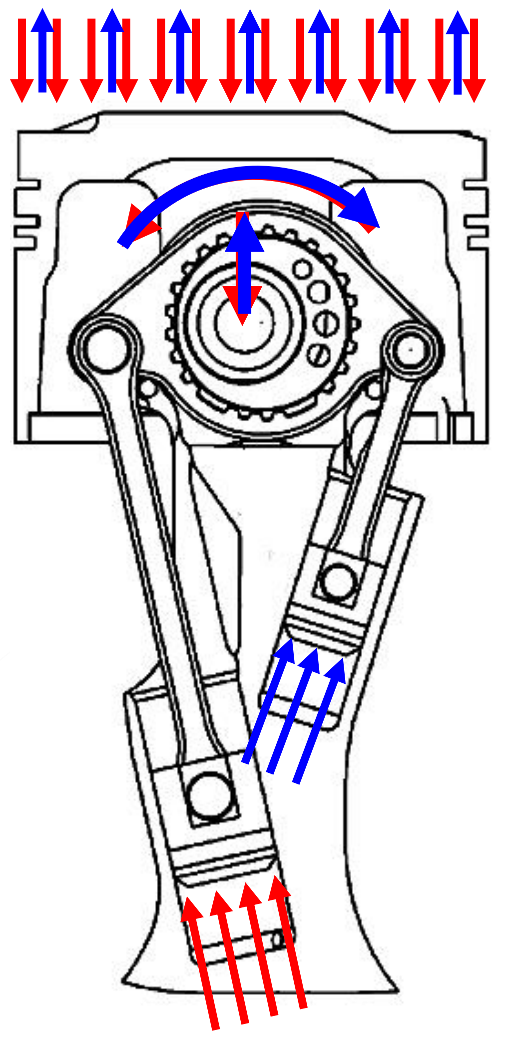
- SI engines
- Production state
- Model year > 1997



Powertrain Control and Optimization for Future Fuel Efficiency
Development Trends – Variable Compression Ratio (VCR)

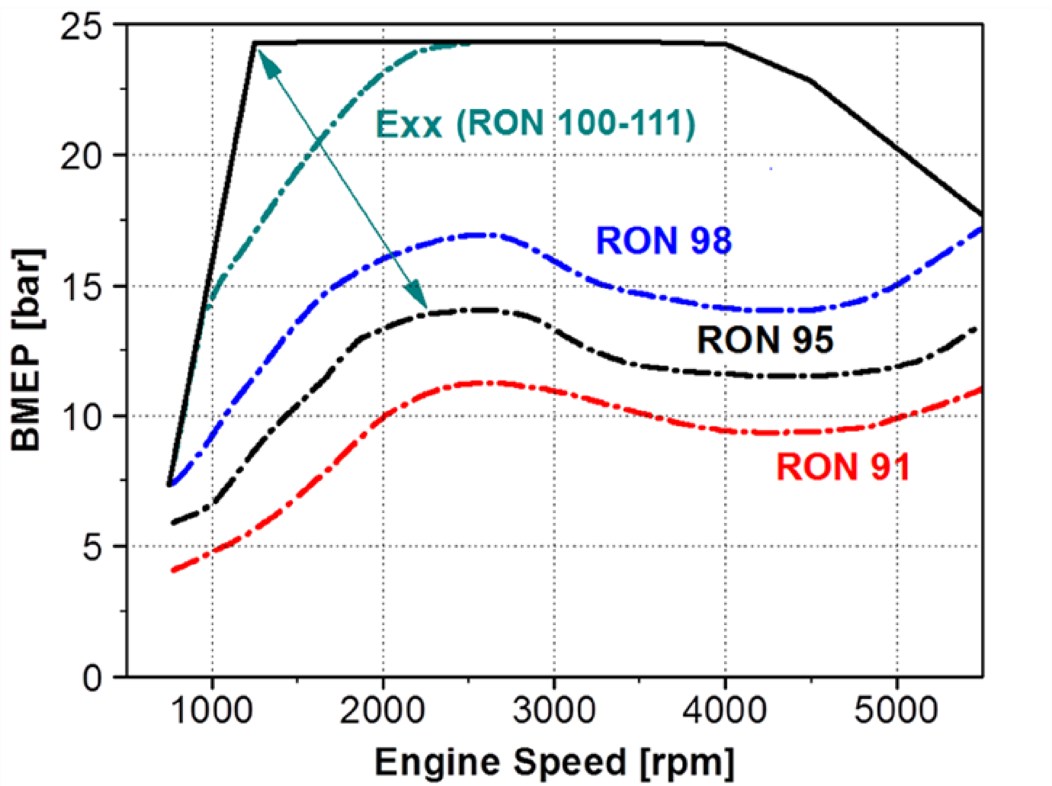
Working Principle:





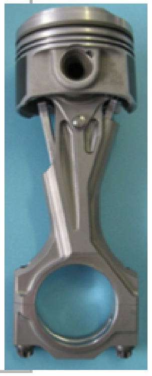
Powertrain Control and Optimization for Future Fuel Efficiency
Development Trends – Variable Compression Ratio (VCR)

2.0l, TC, Two-Stage VCR 8/12 (optimized for RON 95)



Remarks

- New, additional fuels will enter the market
- Fuels like Ethanol (RON 111) or CNG (RON 130) have a significant higher octane rating
- VCR systems allow an optimized CR depending on the utilized fuel



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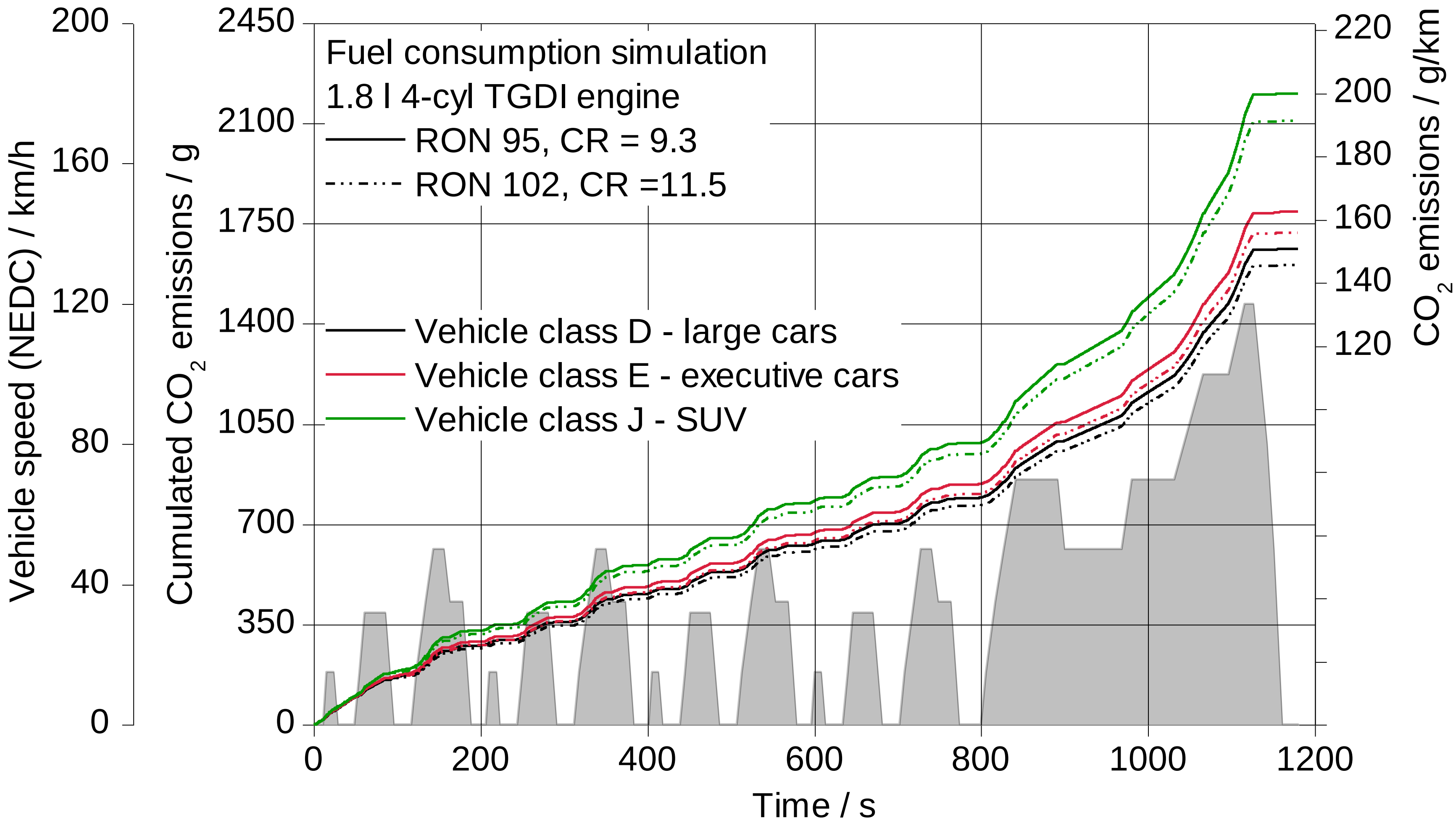
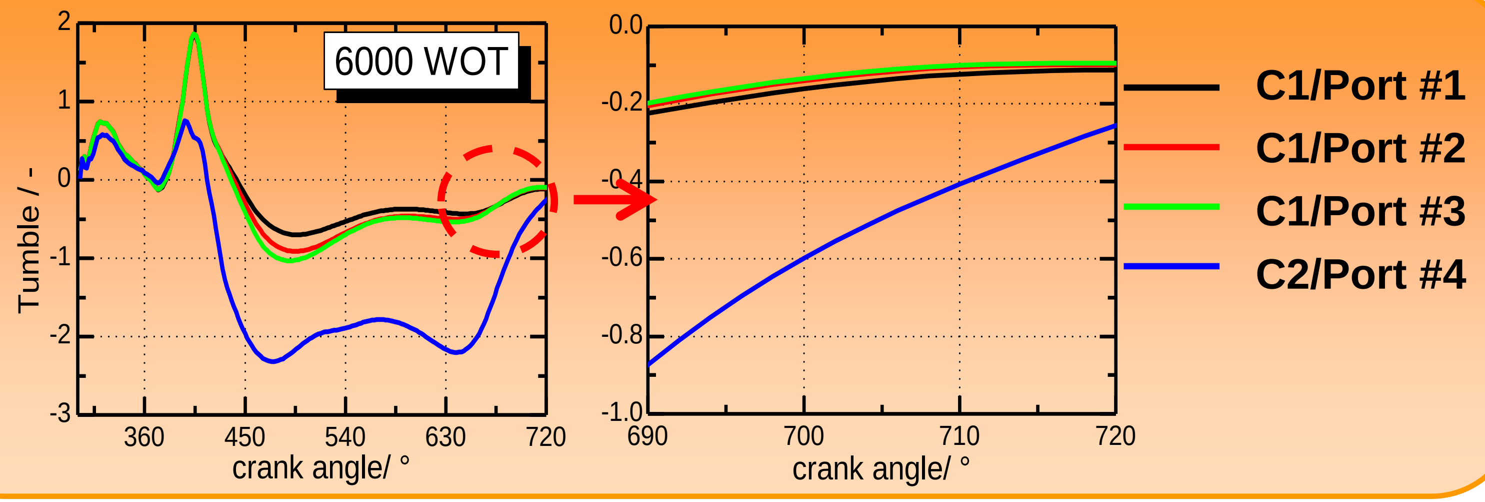
Powertrain Control and Optimization for Future Fuel Efficiency
Development Trends – VCR and RON Potential

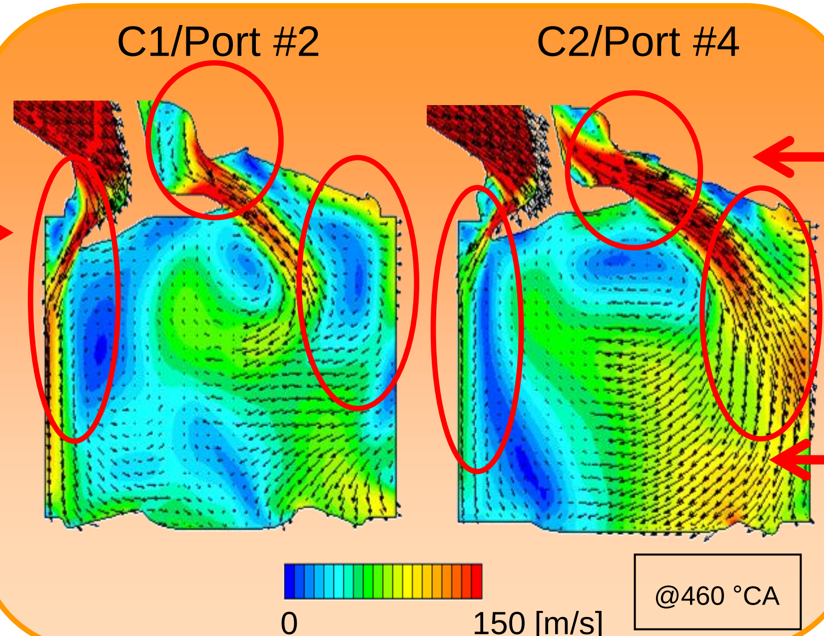


Vehicle CO_2 emissions can be reduced by ~ 3 – 5 % with high octane fuels and adapted engines with increased compression ratio

Powertrain Control and Optimization for Future Fuel Efficiency Development Trends – Combustion System Development (CMD Process)



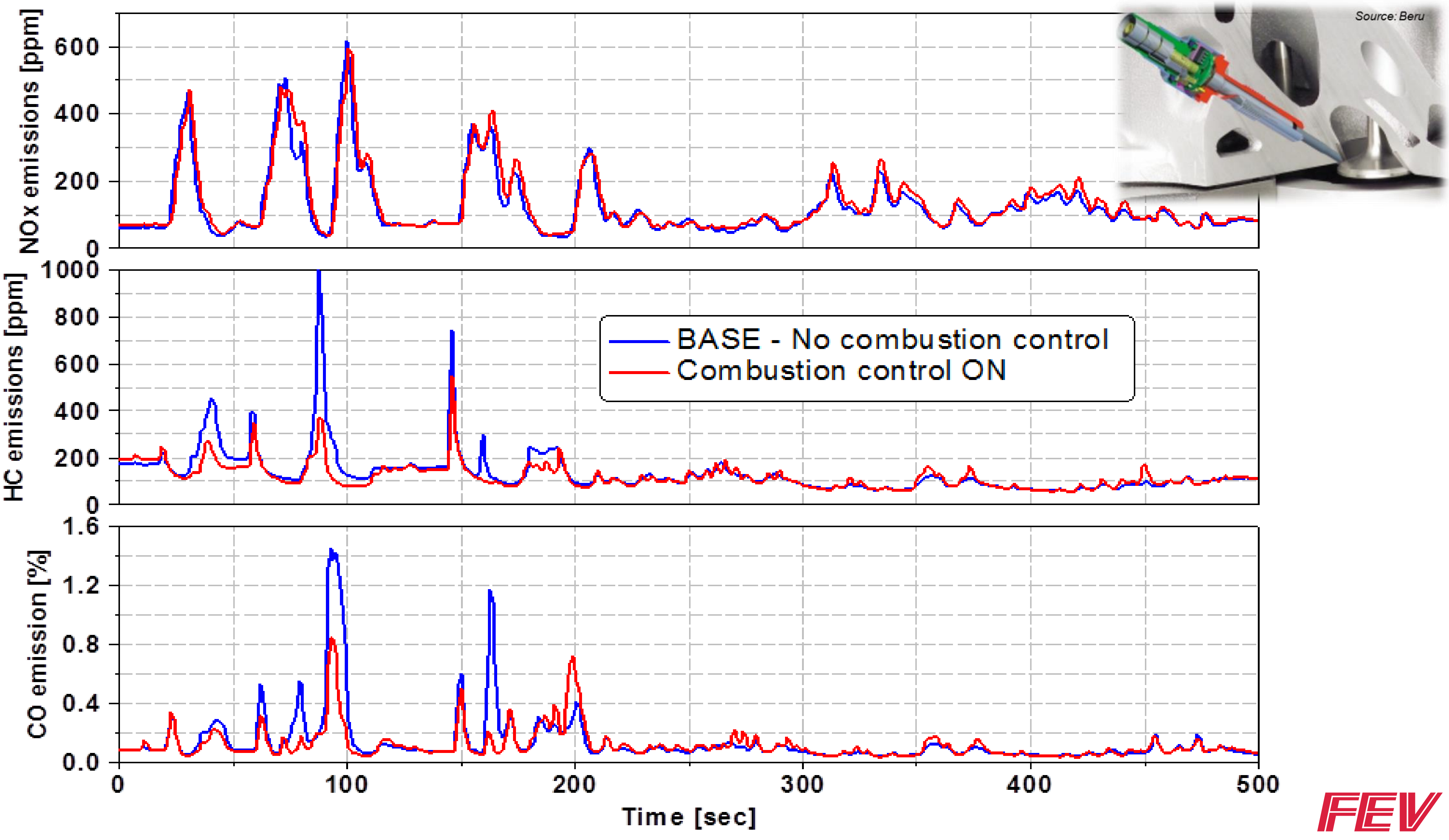
Decreased mass flow over the backside of the valve (better separation of the flow)



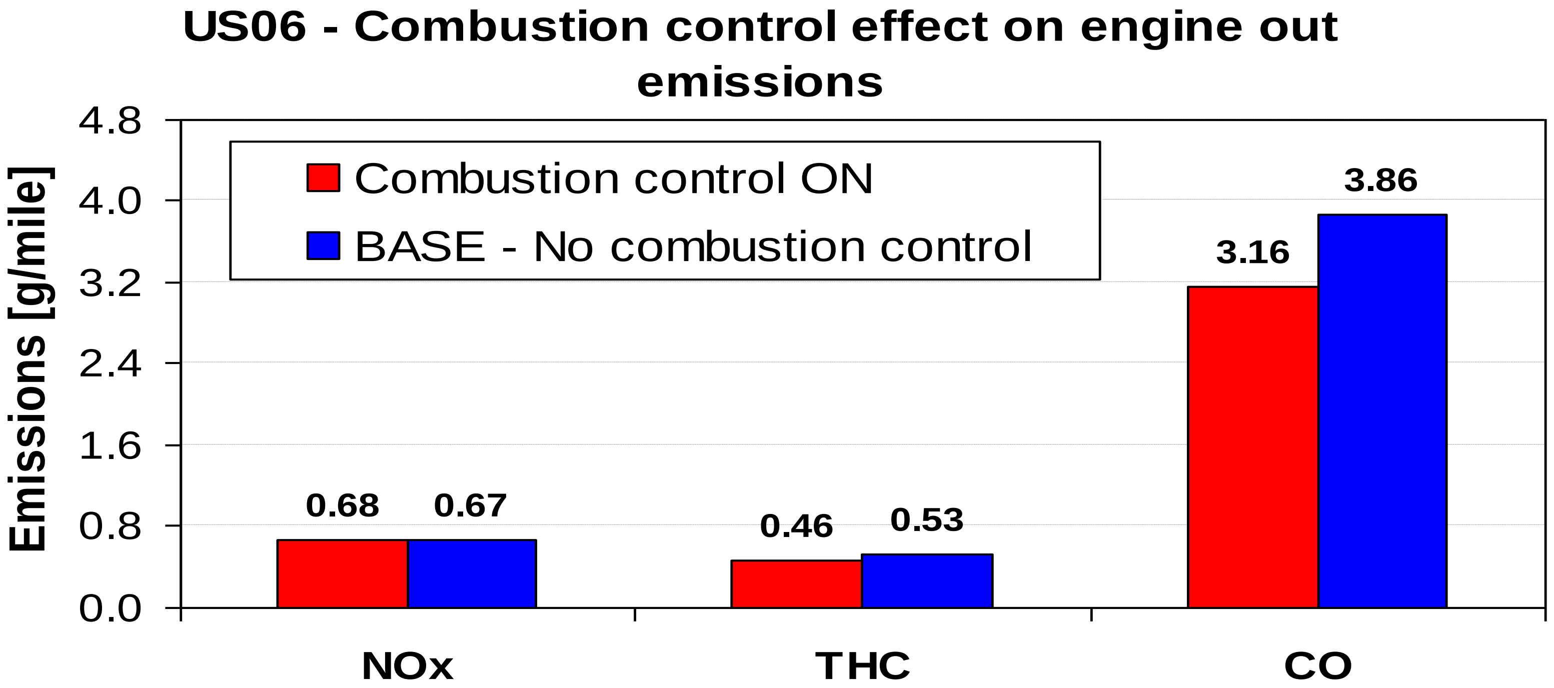
High mass flow over front side following head contour

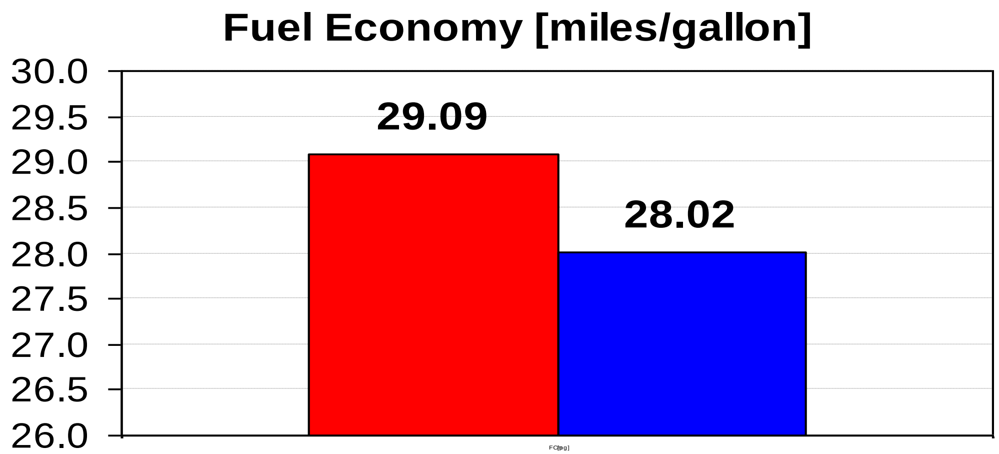
Robust tumble structure

Powertrain Control and Optimization for Future Fuel Efficiency Development Trends – Closed Loop Combustion Control (CLCC)

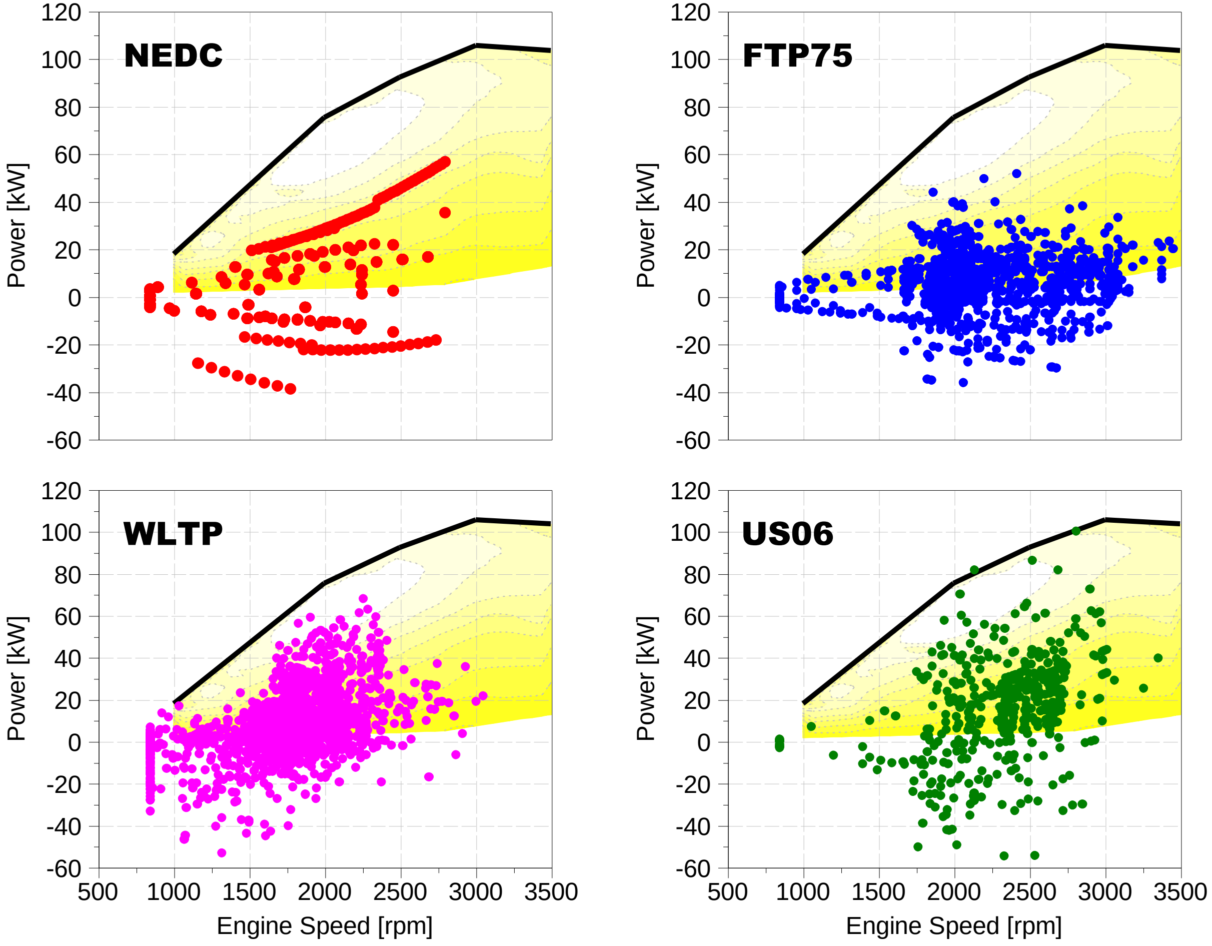


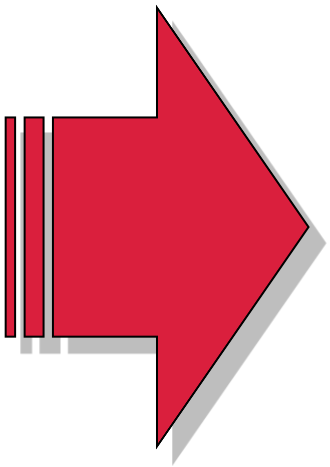
Powertrain Control and Optimization for Future Fuel Efficiency Development Trends – Closed Loop Combustion Control (CLCC)





Powertrain Control and Optimization for Future Fuel Efficiency Development Trends – Standard Test Cycles vs. Real World

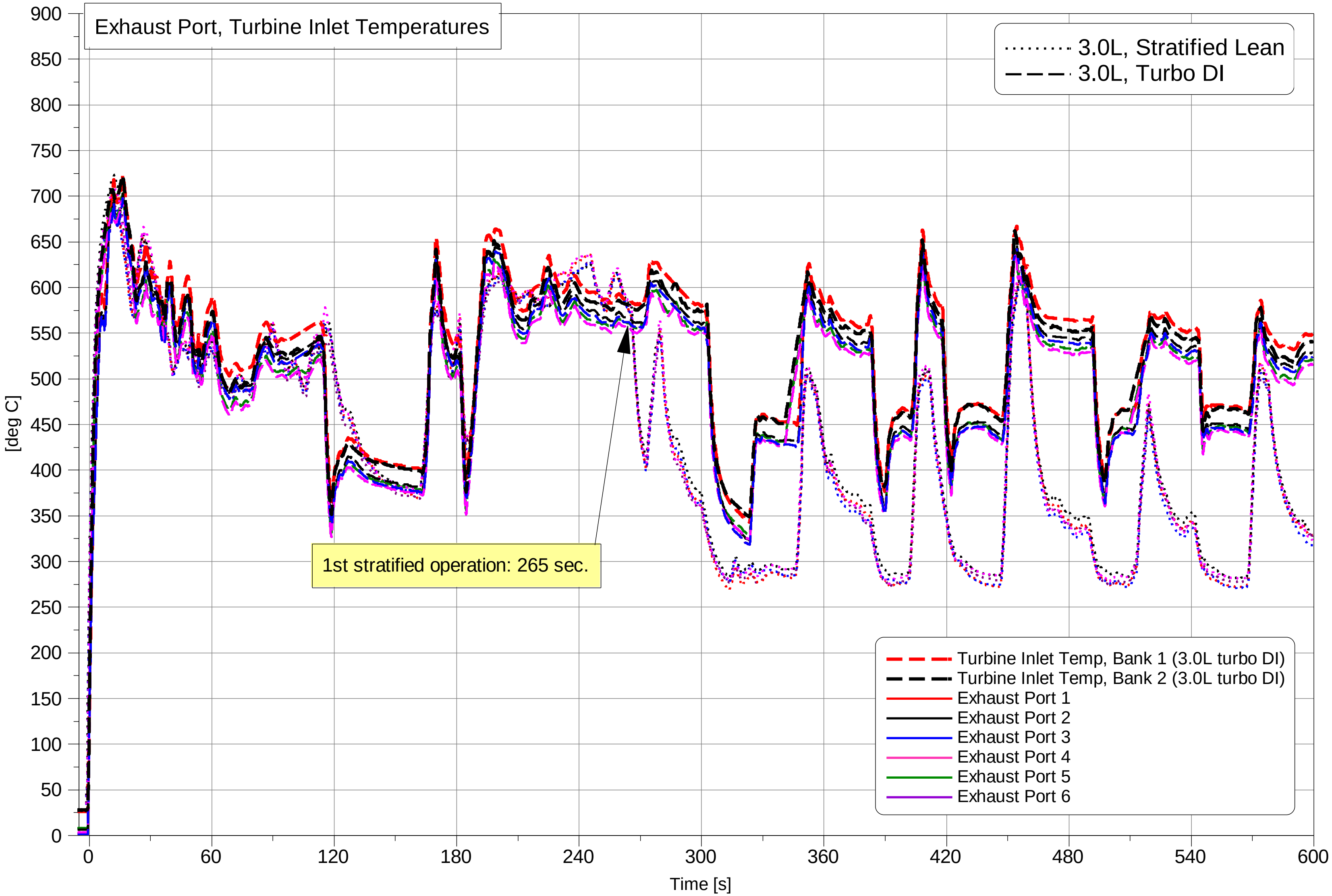




Real World Driving?

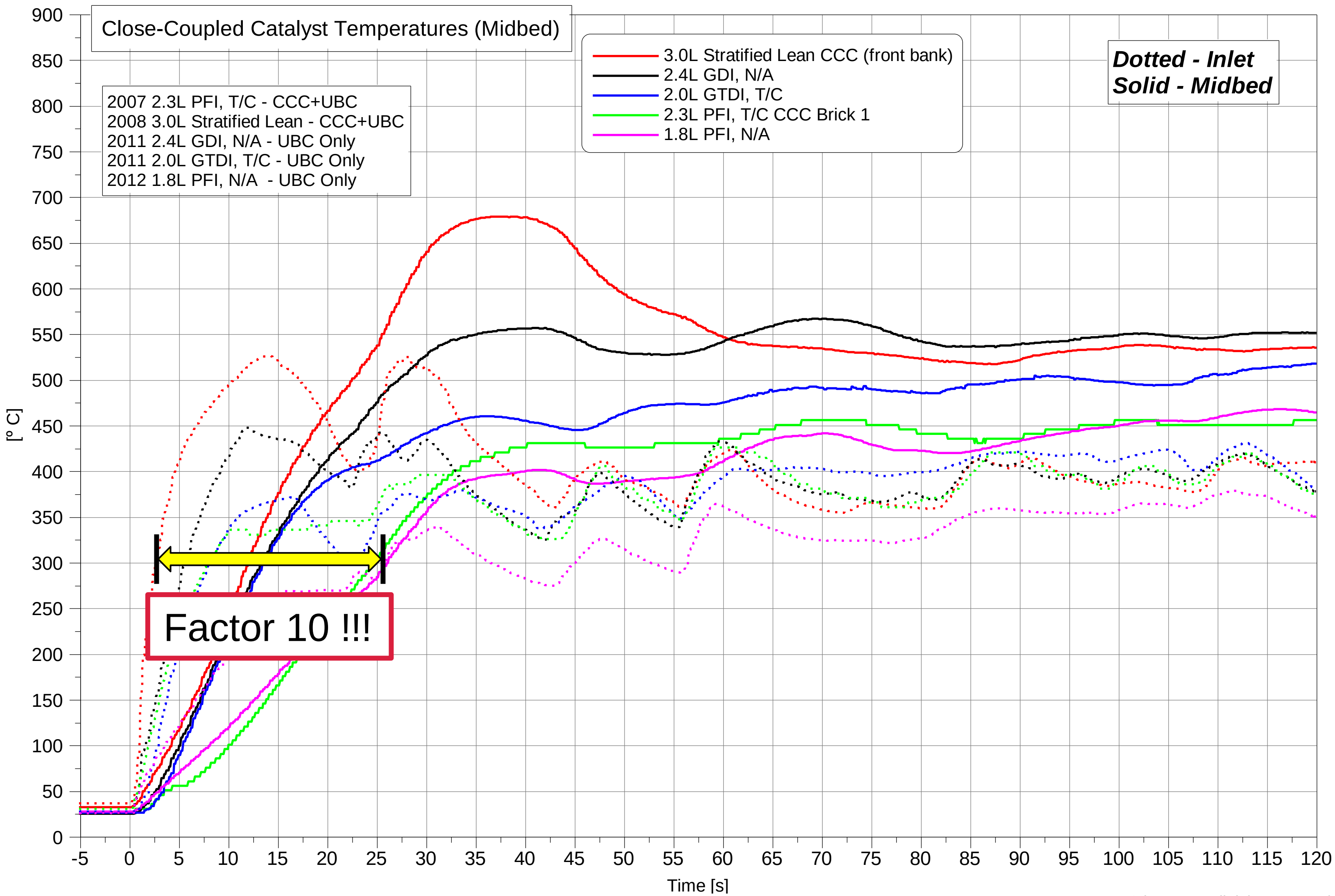
FTP75 and US06 are more wide spread compared to NEDC. The WLTP is closer to US cycles.

Powertrain Control and Optimization for Future Fuel Efficiency Development Trends – FTP-75 Exhaust Gas Temperatures (Gasoline)



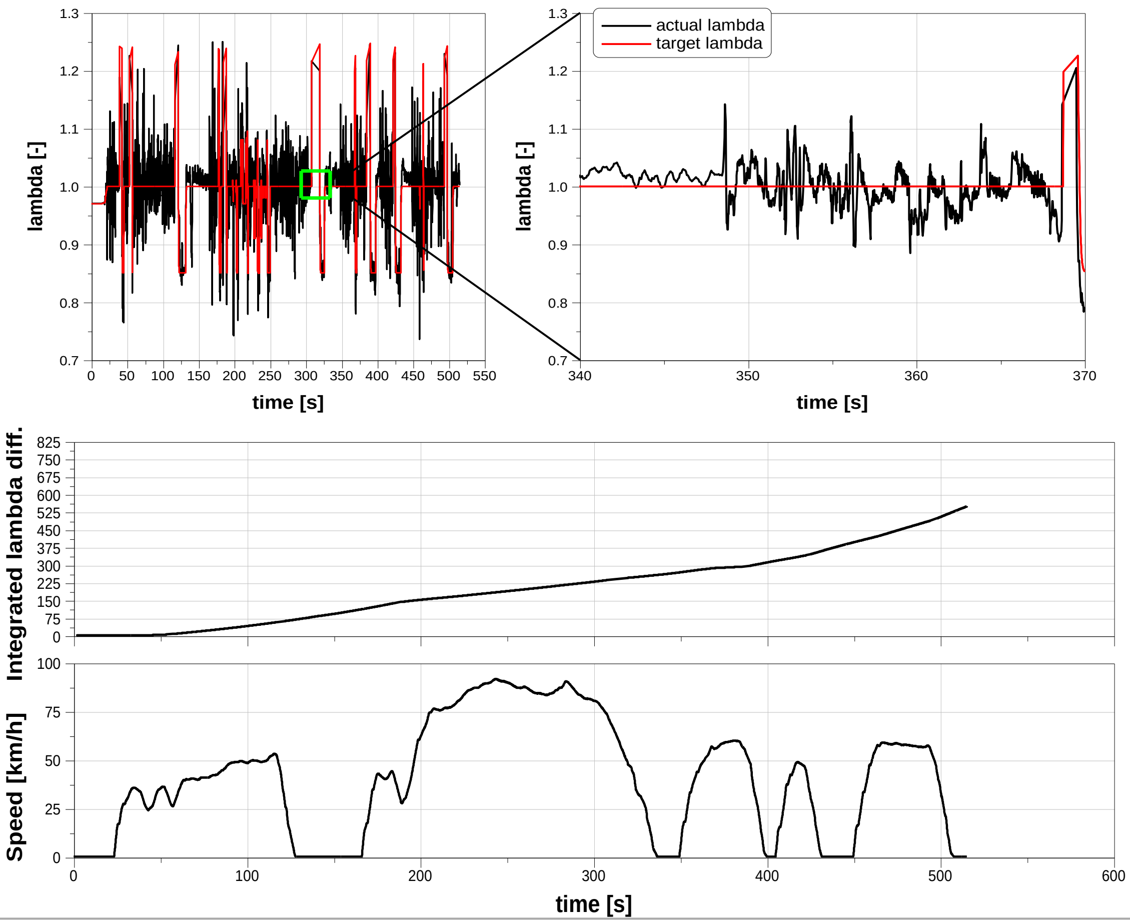
Powertrain Control and Optimization for Future Fuel Efficiency Development Trends – Cold Start Exhaust Gas Temperatures (Gasoline)

Vehicle Cold Start Testing: FTP 75 C/H, 25º C



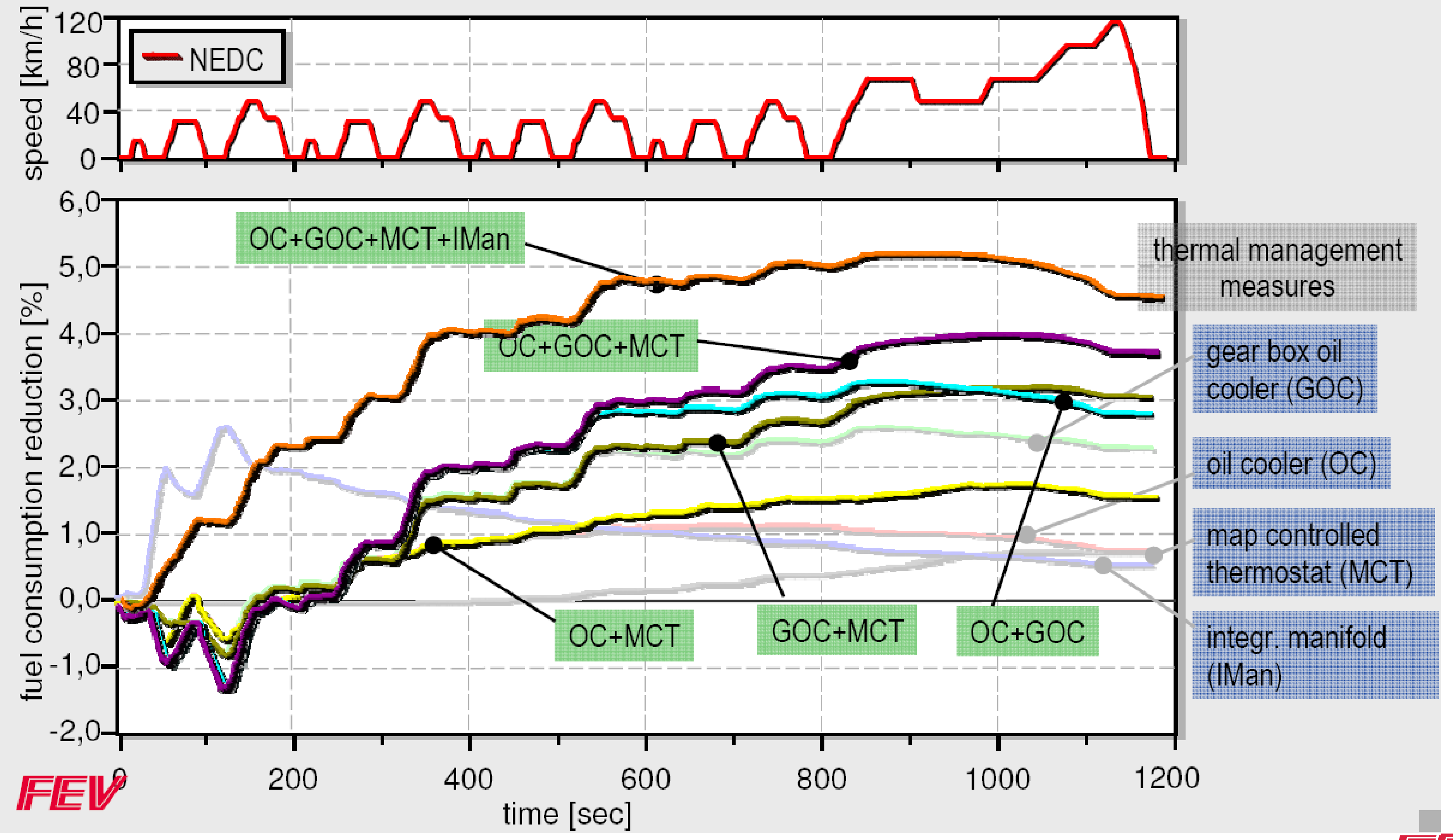
Powertrain Control and Optimization for Future Fuel Efficiency Development Trends – Lambda Control (Gasoline)

Lambda Control	Conclusion



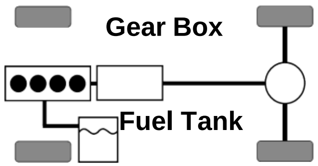
- Lambda controller typically consists of a feed forward controller combined with a feedback loop control principle
- As the closed loop part is driven by deviation, an error has to occur before corrective measures are taken
- The integrated absolute deviation between target lambda and actual lambda shows performance of the lambda controller, ideal this would be zero
- Better open loop control could reduce the CO_2 emissions

Powertrain Control and Optimization for Future Fuel Efficiency
Development Trends – Thermal Management Options (Gasoline)



Powertrain Control and Optimization for Future Fuel Efficiency
Development Trends - Hybridization

Conventional Vehicles



Hybrid Electric Vehicles

Micro Hybrid	Mild Hybrid	Full Hybrid	Plug-In Hybrid
			+ Plug-In/REX
		+ Electric Drive	+ Electric Drive
	+ Kinetic Energy Recovery & Boosting	+ Kinetic Energy Recovery & Boosting	+ Kinetic Energy Recovery & Boosting
Start-Stop & Intelligent Energy Management	Start-Stop & Intelligent Energy Management	Start-Stop & Intelligent Energy Management	Start-Stop & Intelligent Energy Management

Increasing electrical power

Battery size/price

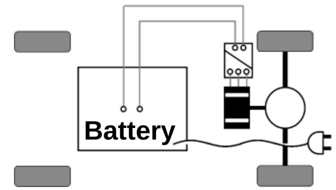
CO_2-Emissions

Complexity Transmission

Complexity ICE

Downsizing Diesel and Gasoline — Gasoline NA — Gasoline Atkinson

Battery Electric Vehicles



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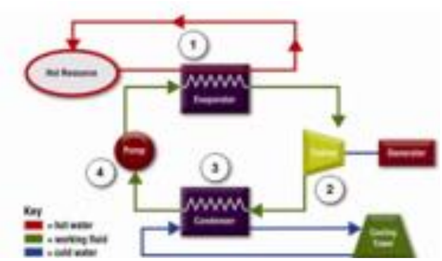
Powertrain Control and Optimization for Future Fuel Efficiency Development Trends – Waste Heat Recovery

Introduction to Waste-Heat Recovery Technologies

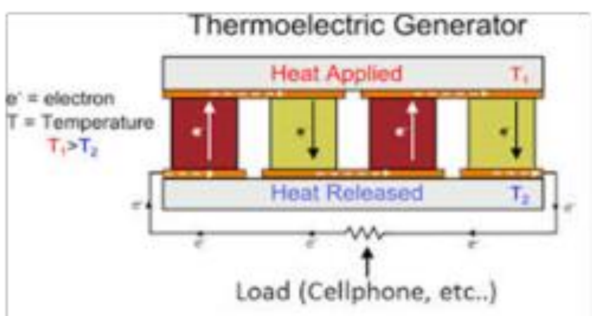
Organic Rankine Cycle (ORC)

- The Rankine Cycle is a thermodynamic cycle that converts heat into work
- The heat is supplied externally to a closed loop, which uses water or another fluid as working fluid.



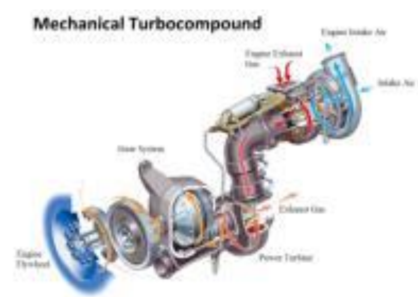
Thermoelectric Generator (TEG)

- Temperature difference between the hot and cold surfaces of the thermoelectric module(s) generates electricity using the Seebeck Effect



Turbocompound

- A turbine recovers energy from the exhaust gas
- Three main forms: Mechanical Turbocompound, Electric turbocharger, Turbogenerator



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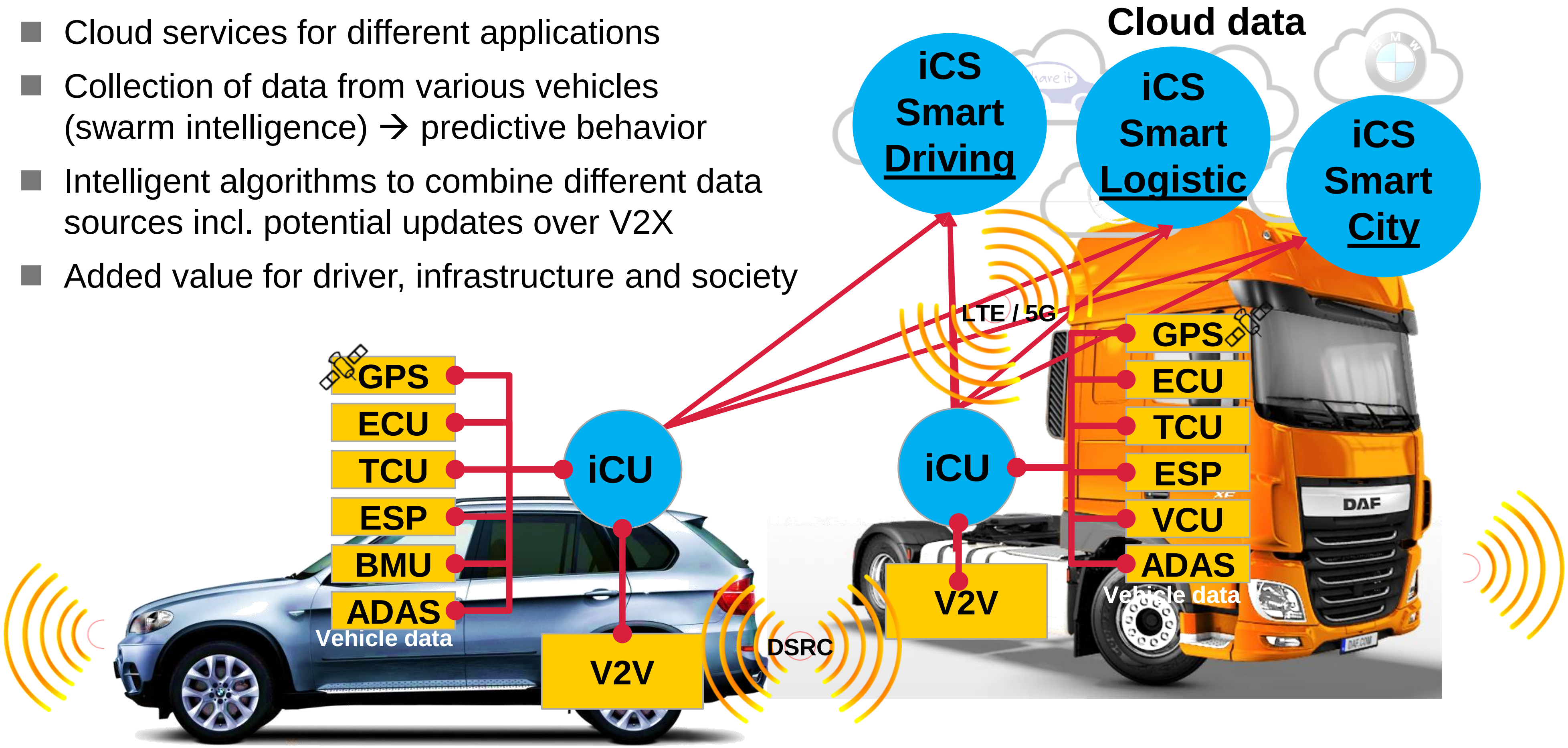
Potential of Vehicle Connectivity

Potential Scenario and Benefits:

- Establish intelligent connection unit/service (iCU/iCS)
- Cloud services for different applications
- Collection of data from various vehicles (swarm intelligence) → predictive behavior
- Intelligent algorithms to combine different data sources incl. potential updates over V2X
- Added value for driver, infrastructure and society



Source: DAF, BMW

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Powertrain Control and Optimization for Future Fuel Efficiency
Summary and Outlook

- Significant improvement of fuel economy and emissions based on legislation are impetuous yet mandatory.
- Engine technologies in combination with advanced controls in the field of engines, transmissions, aftertreatment, hybridization, thermal management, etc., offer significant potential for improvement beyond the current state-of-the-art allowing to meet the legislated targets for 2025.
- In addition, vehicle connectivity provides additional potential which, when properly applied, further improves vehicle fuel economy while simultaneously improving driving comfort and vehicle/passenger safety.
- More work in the area of powertrain and vehicle connectivity is required to not only achieve improvement in their corresponding fields but also to connect the two with each other allowing to maximize the gain in overall vehicle fuel economy.