U.S. DEPARTMENT OF ENERGY

DEER 2010 DETROIT

DIRECTIONS IN ENGINE-EFFICIENCY AND EMISSIONS RESEARCH CONFERENCE

Future Directions in Engines and Fuels

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DEER 2010

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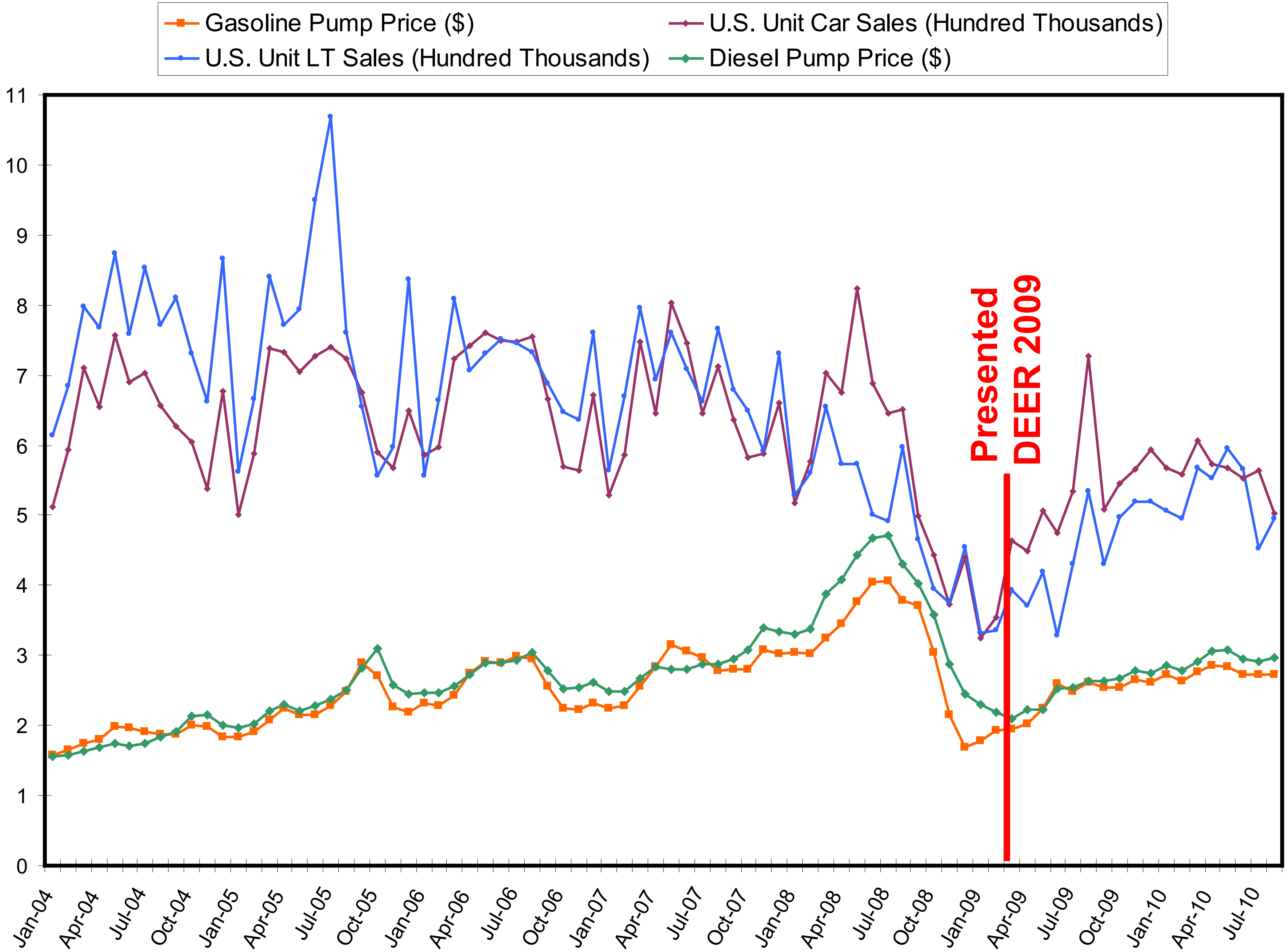
Future Directions in Engines and Fuels
Market Trend Observations – Past Year Review

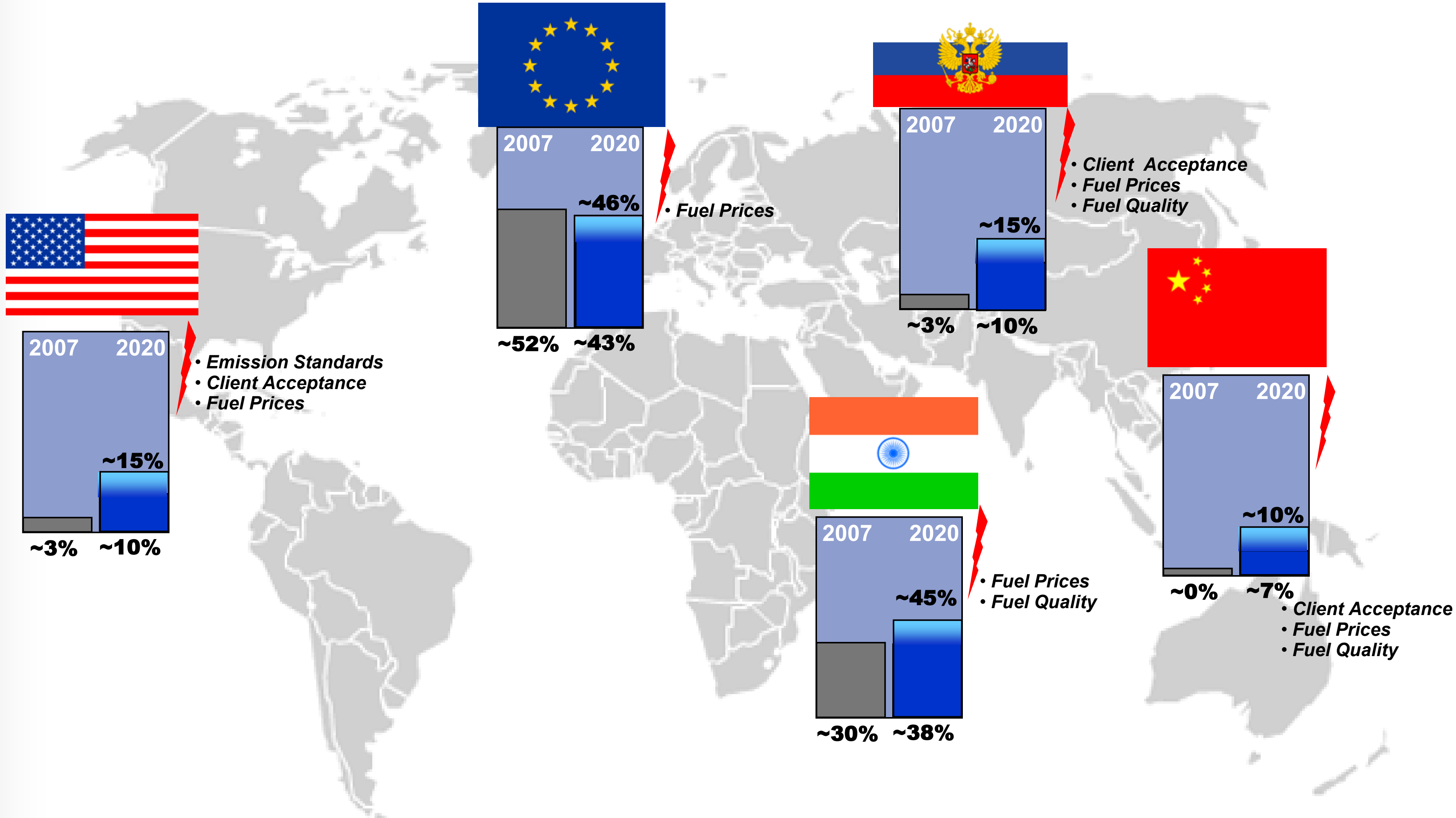


Source: www.bts.gov ; www.eia.doe.gov
www.automotivenews.com

Global Market Development Diesel – PC & LD

Light Duty Diesel – Quo Vadis?

Future Directions in Engines and Fuels
Global Market Development Diesel – PC & LD



Future Directions in Engines and Fuels
Future Diesel Drivetrain Scenarios

					
		Segment / Technology	Small	Medium	Large
Diesel	Engine	Downsizing	Not feasible? (1.3l)→(1l)?	(2l) → (1,6l) -20%	(3lV6) → (2,2l I6/I4) -30%
		Boosting	Optimized VNT	1/2-stage	2-stage
		FIE	1450..1800 bar	1800-2000 bar (Piezo)	>2000 bar Piezo
		EGR-System	HP/HP&LP-EGR	HP&LP-EGR	HP&LP-EGR
		Optimized Combustion	Lowered Compr.	Lowered Compr.	Lowered Compr.
		Aftertreatment	DPF / LNT	DPF / SCR or DPF / LNT	DPF / SCR
	Transmission	Manual / Automated	AMT, DCT	AMT, DCT, AT	AT, DCT
		Gears	5-6	6-8	6-8
		Clutches Dry / Wet	Dry	Wet, Dry	Wet
		Electric / Hydraulic	Electrical	Electr., Hydr.	Hydr.
	Hybrid	Start/Stop	BISG	BISG & ISG	ISG
		Rekuperation	Restricted, 3KW	Enhanced	Full
		Optimized Operation	Limited	Limited	Yes
		Electric Drive (<20mi)	-	-	Yes

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Boundary Conditions: U.S. Tier 2 Bin 5

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FEV *HECS* Engine Specifications

	HECS Engine
BoreXStroke	75x88.2 mm
Displacement	1.6L (4x390 cm^{3})
Compression ratio	15.5
Valves per cylinder	4
Max. valve lift	8 mm
Maximum cylinder peak pressure	220 bar
Fuel injection equipment specifications:	Piezo Common Rail System (CP4.1, CRI 5.1)
Max. injection pressure	2000 bar
HFR	310 cm^3/60s@100bar
Max. boost pressure	3.75 bar (2-stage)
Charge air cooling level	Advanced
Variable swirl	Yes (with VVL)
Glow plug	Yes
EGR	Internal, HP and LP EGR
Combustion control	Center of combustion, maximum burning rate, IMEP Control
Emission level	Euro 6+

HECS: High Efficiency Combustion System

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FEV *HECS* Diesel Concept Car

Specification *HECS* I (current)

- 1.6l 4-Cyl. Diesel Engine
- 60 kW/l spec. Power (limited PFP)
- Euro 6 w/o DeNOx (<1700 kg)
- ~130g/km CO_2 (1590 kg)
- 2-stage boosting system
- High (cooled) and Low Pressure EGR
- Advanced Cooling Concept
- 2000 bar Piezo FIE
- Optimized Bowl with CR 15:1
- Exhaust Cam Phaser
- Model based Air path control
- Closed loop combustion control

Specification *HECS* II

- 1.6l 4-Cyl. Diesel Engine
- 80 kW/l spec. Power (200 bar PFP)
- Euro 6 w/o DeNOx (<1700 kg)
- ~120g/km CO_2 (1590 kg)
- 2-stage boosting system
- High and Low Pressure EGR
- Advanced Cooling Concept
- Split&intelligent cooling engine
- 2000 bar Piezo FIE
- Optimized Bowl with CR 15:1
- Variable Swirl Concept (VVL)
- Exhaust Cam Phaser
- Model based Air path control
- Closed loop combustion control
- Start & Stop

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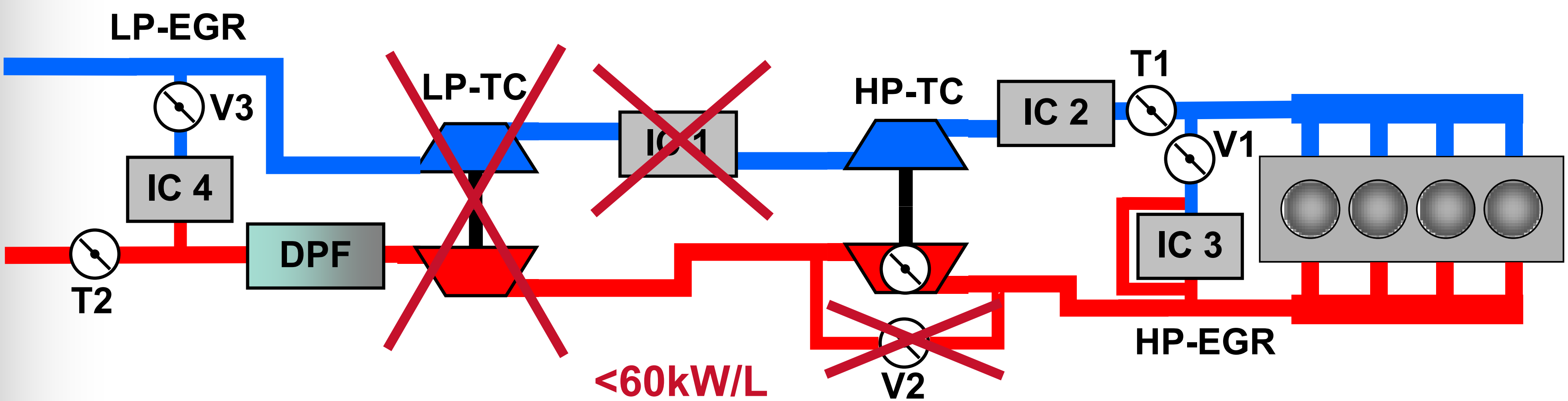
Future Directions in Engines and Fuels
2-Stage Charging and EGR Concept

Calculation Results Series-TC:

- power target at n=1000 rpm not reached (larger HP-turbine), torque slightly above baseline engine; further H/W optimization feasible
- all other power targets can be reached, but LP-compressor is very close to choke line at high engine speeds
- at n=4500 rpm quite high exhaust back pressure rise due to decreasing LP-compressor efficiency (could be optimized)
- advantage of exhaust back pressure due to higher LP-turbine efficiency



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Heat Exchanger and Coolant Circuit

HP-EGR Cooler:
- ✓ Shell and tubes heat exchanger with optimised gas tube design
- ✓ High thermal exchange and resistance to fouling
- ✓ High permeability
- ✓ U-flow design for additional heat exchange
- ✓ Stainless steel for high resistance to corrosive gases

Intercoolers:
- ✓ Liquid cooled aluminium plate and fin heat exchanger
- ✓ Reduction of gas volume
- ✓ High permeability
- ✓ High thermal performance
- ✓ Higher degrees of freedom with respect to packaging

LP-EGR Cooler:
- ✓ Aluminium plate and fin heat exchanger
- ✓ Compact and permeable design
- ✓ High thermal conductivity
- ✓ Low density

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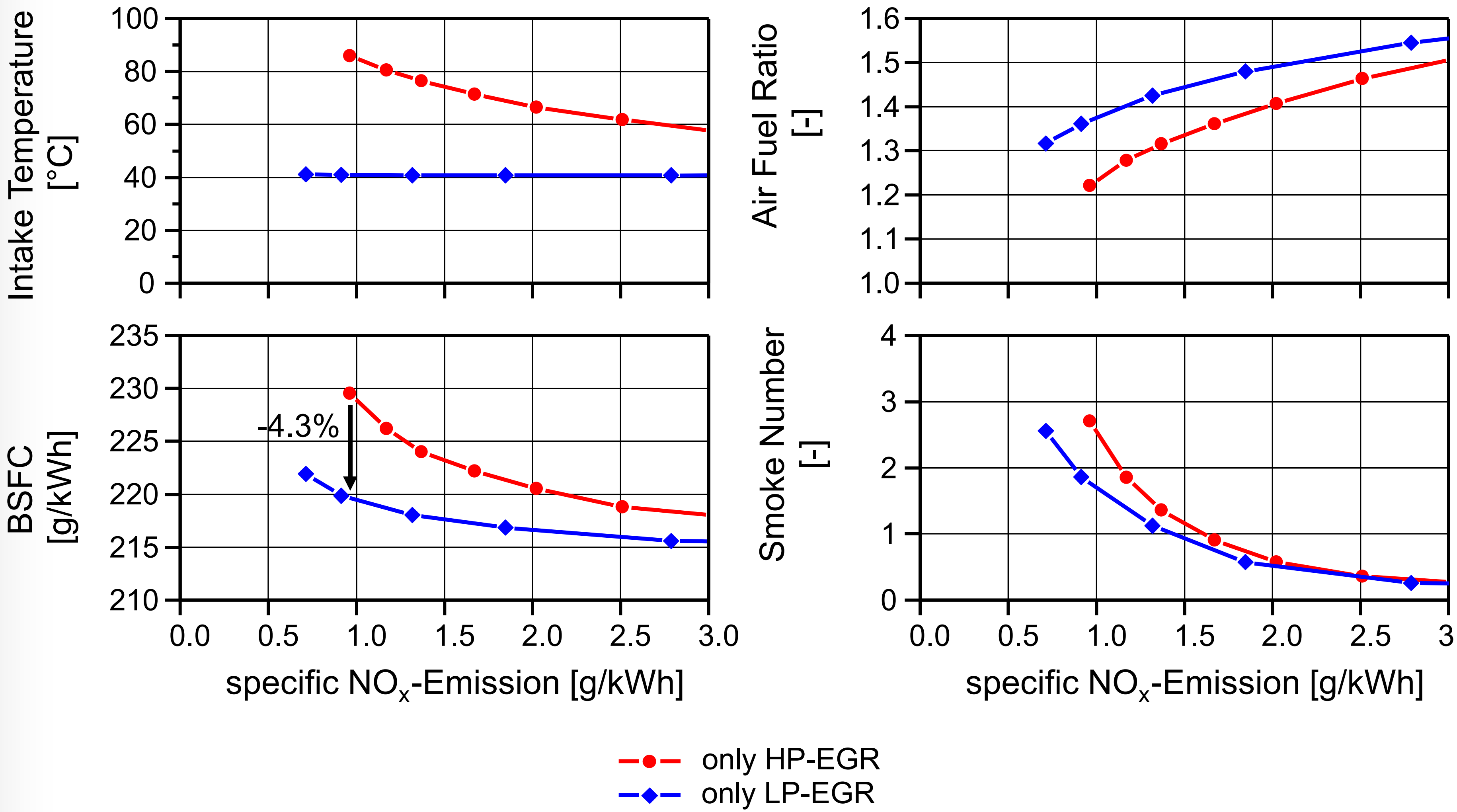
Comparison of EGR Concepts @ 2000 rpm – 12 bar



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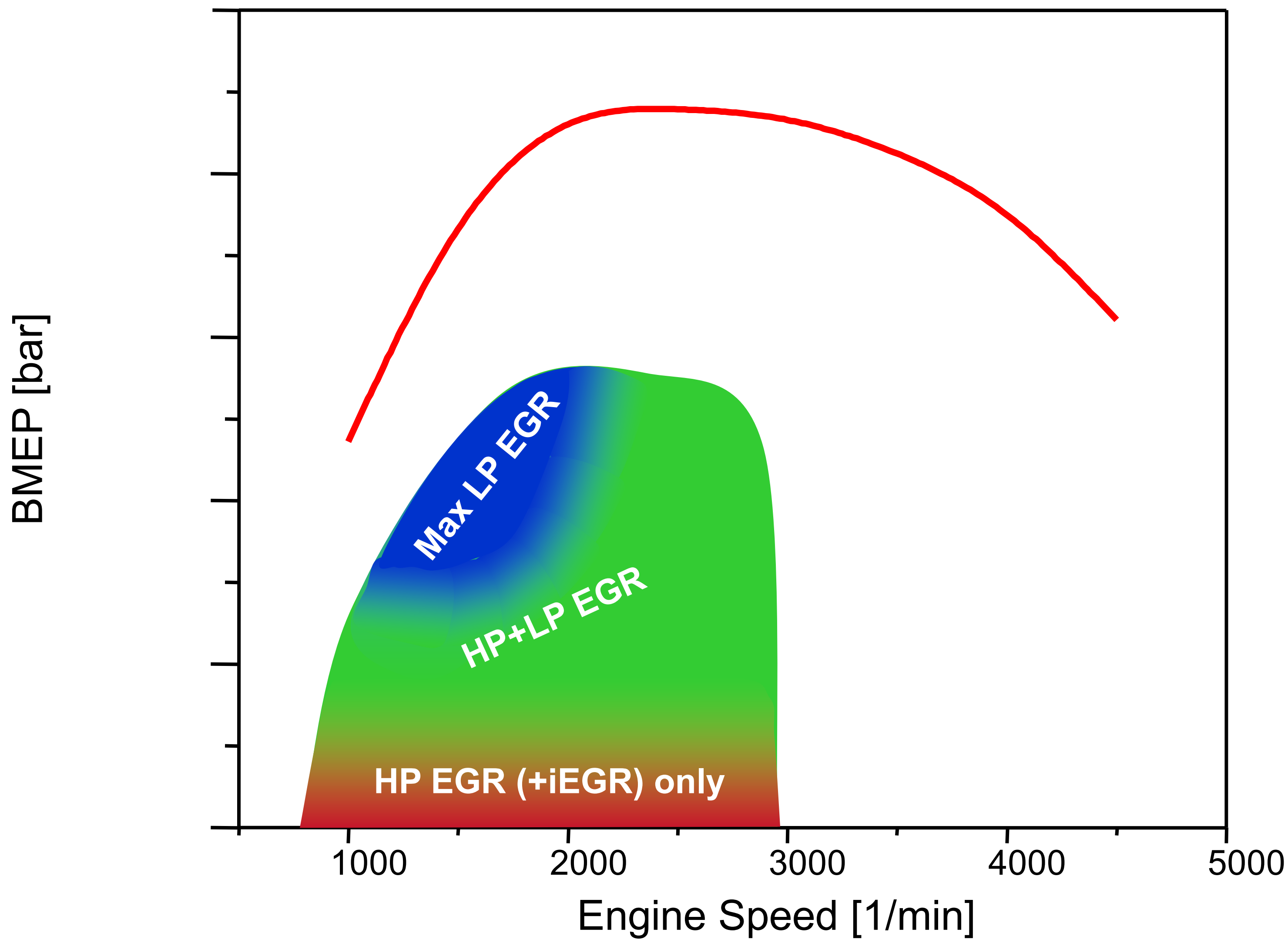
Map of HP – LP EGR Distribution



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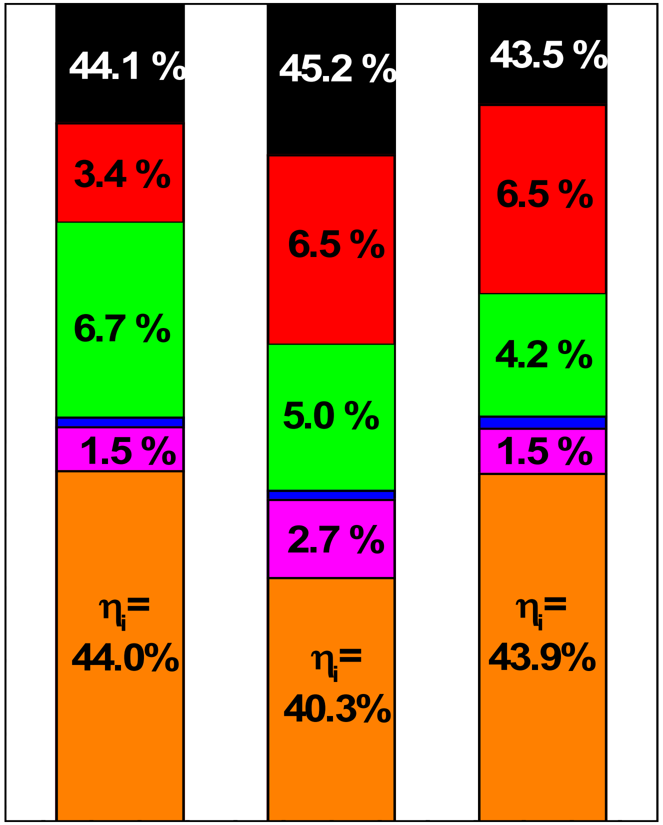
Efficiency Potential

2000 rpm, 12 bar BMEP



EGR point for split of losses

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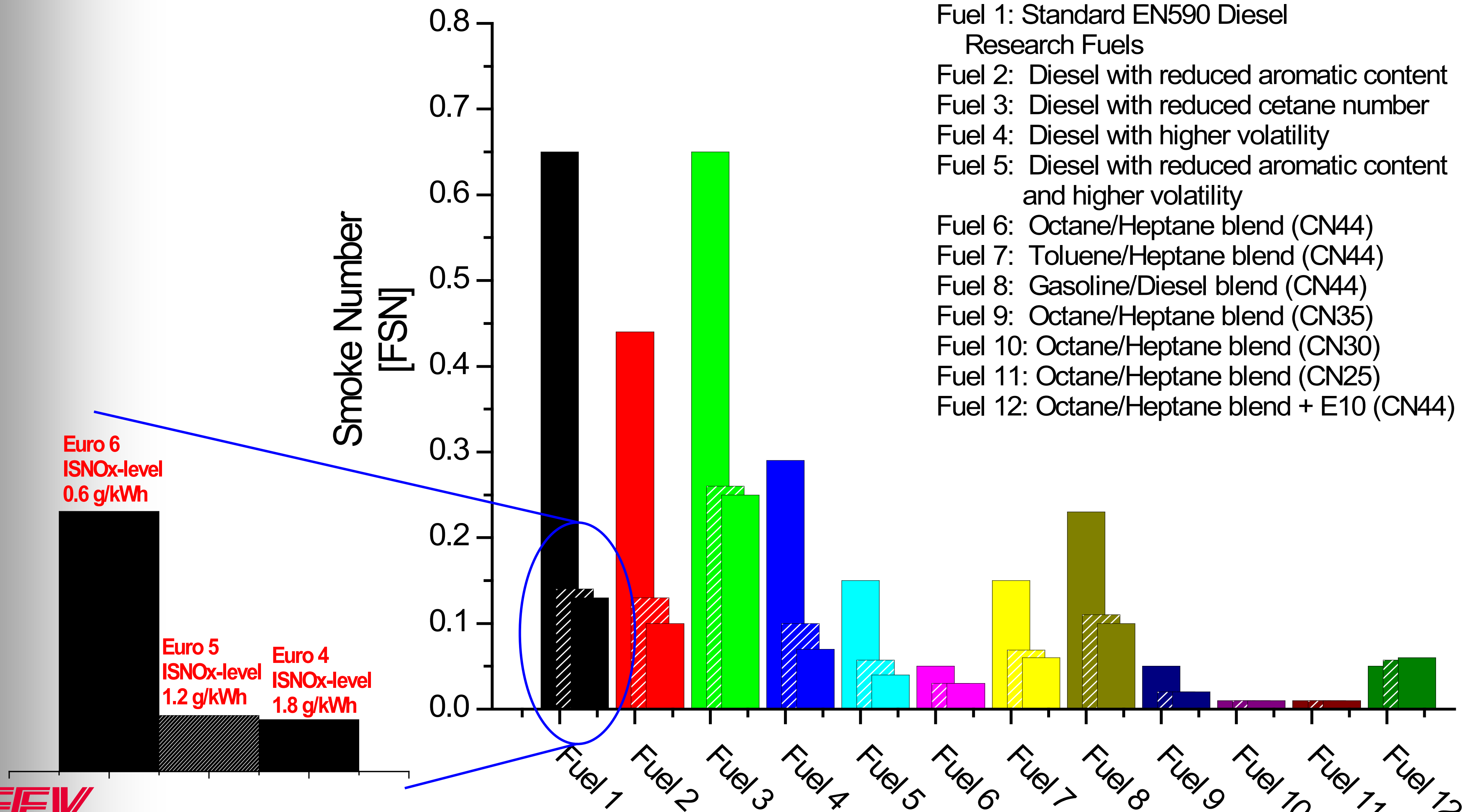
Emission Potential of Advanced Fuel Compositions

Part Load Operation Point: 2300 rpm, high load (*HECS*)



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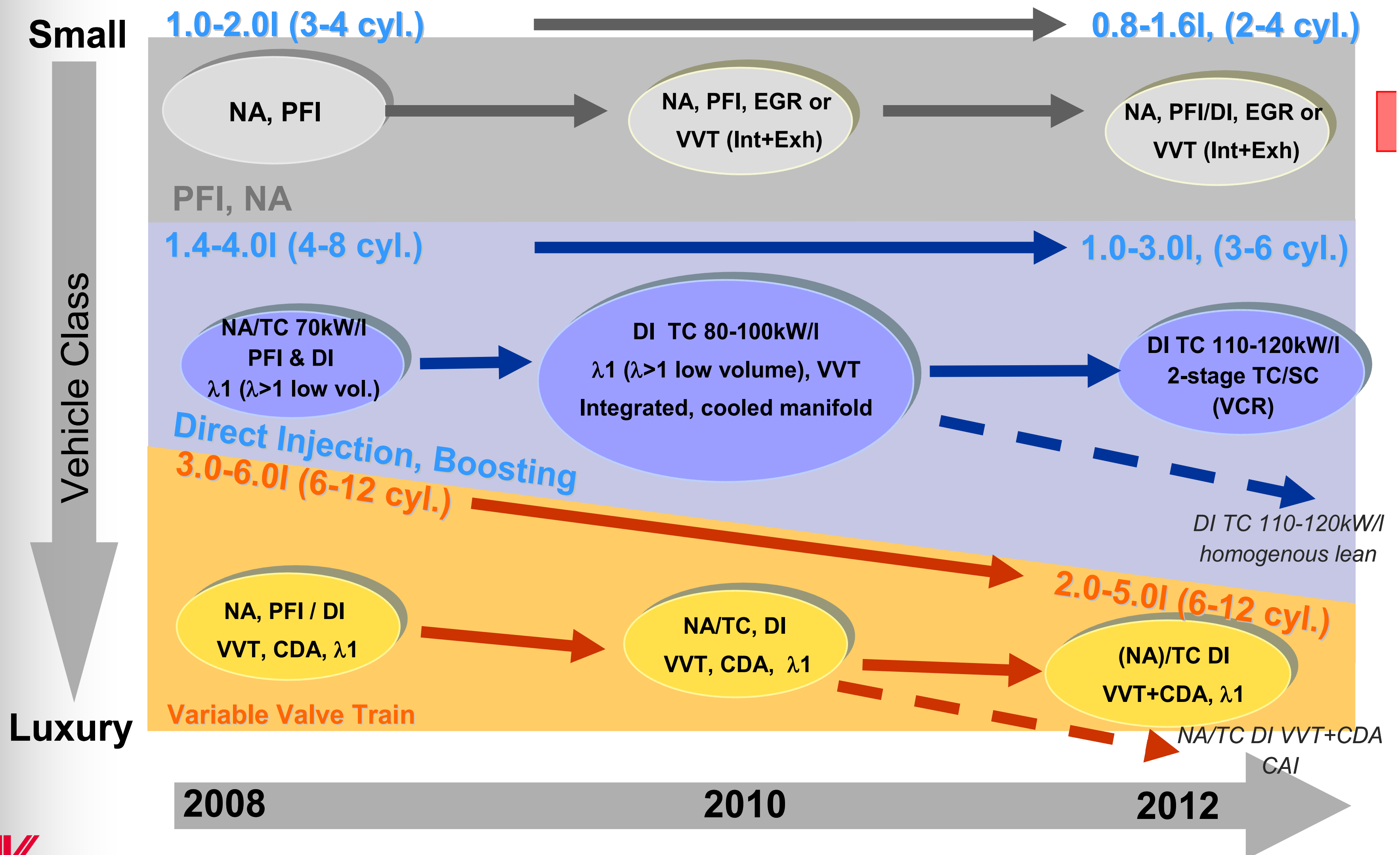
U.S. Light-Duty Gasoline Applications

Light Duty Gasoline Development Trends

Future Directions in Engines and Fuels
U.S. Light-Duty Gasoline Applications



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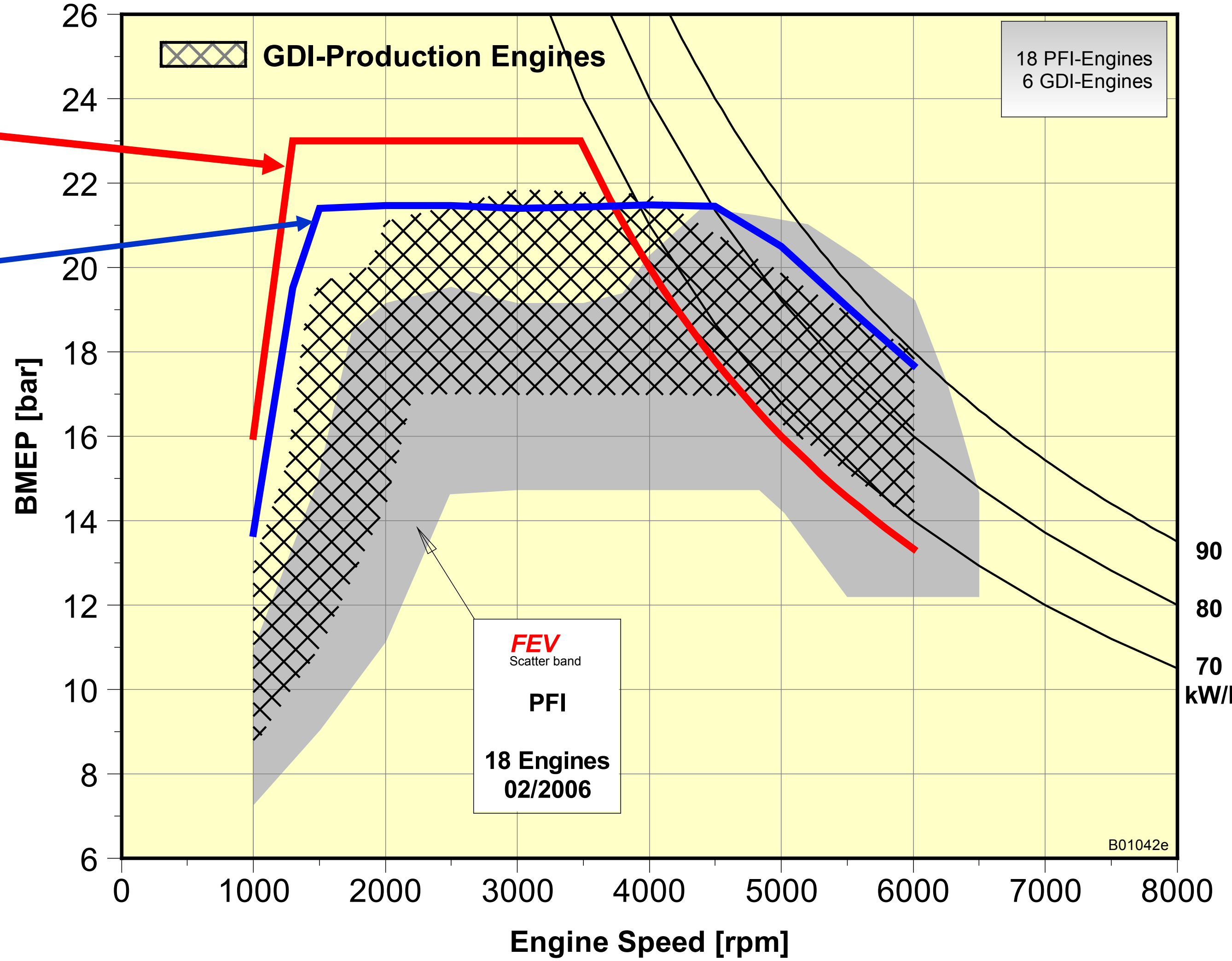
Future Directions in Engines and Fuels
Full Load – State-of-the-Art 3-Cylinder Engine

Target 3 Cylinder

Scatter Range
Future Low End Torque
TC Engines



Brake Mean Effective Pressure

- Standard engines
- Turbocharged

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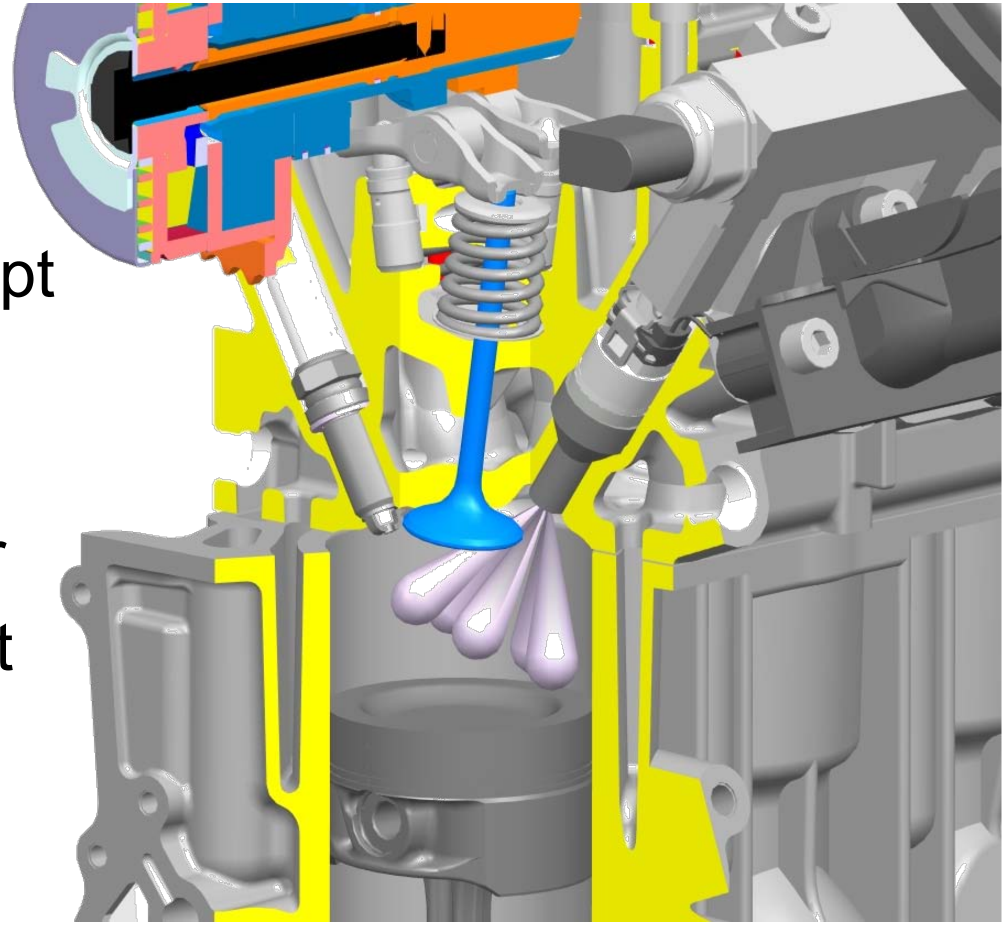
FEV *EDE* (Extreme Downsized Engine)

- Homogenous λ = 1.0 concept
- Multihole solenoid injector
- Assymetric spray pattern
- Single piston pump 200 bar
- Pump is driven by camshaft



→ 100 kW / l – 0.7 l

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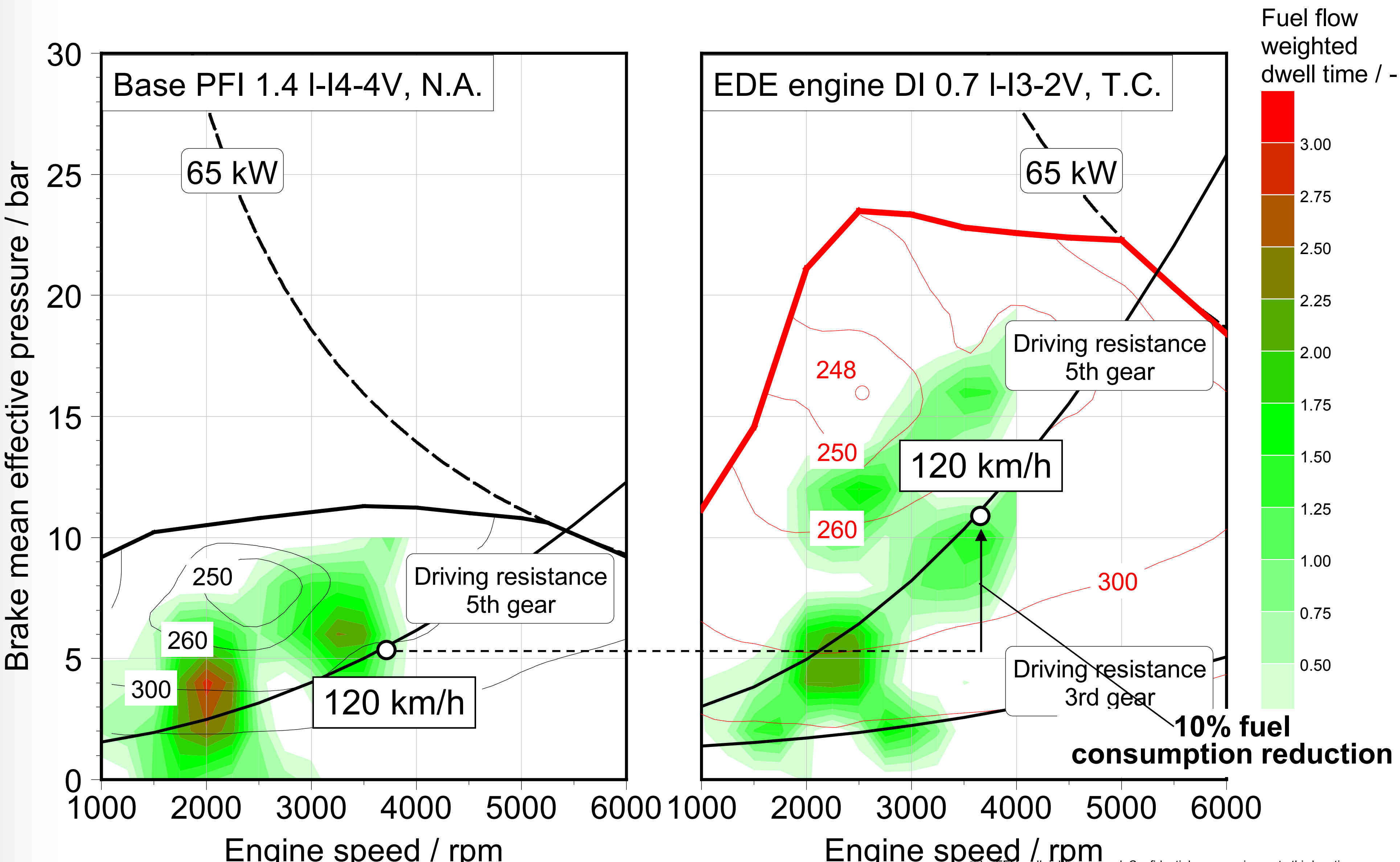
Full Load – State-of-the-Art 3-Cylinder Engine



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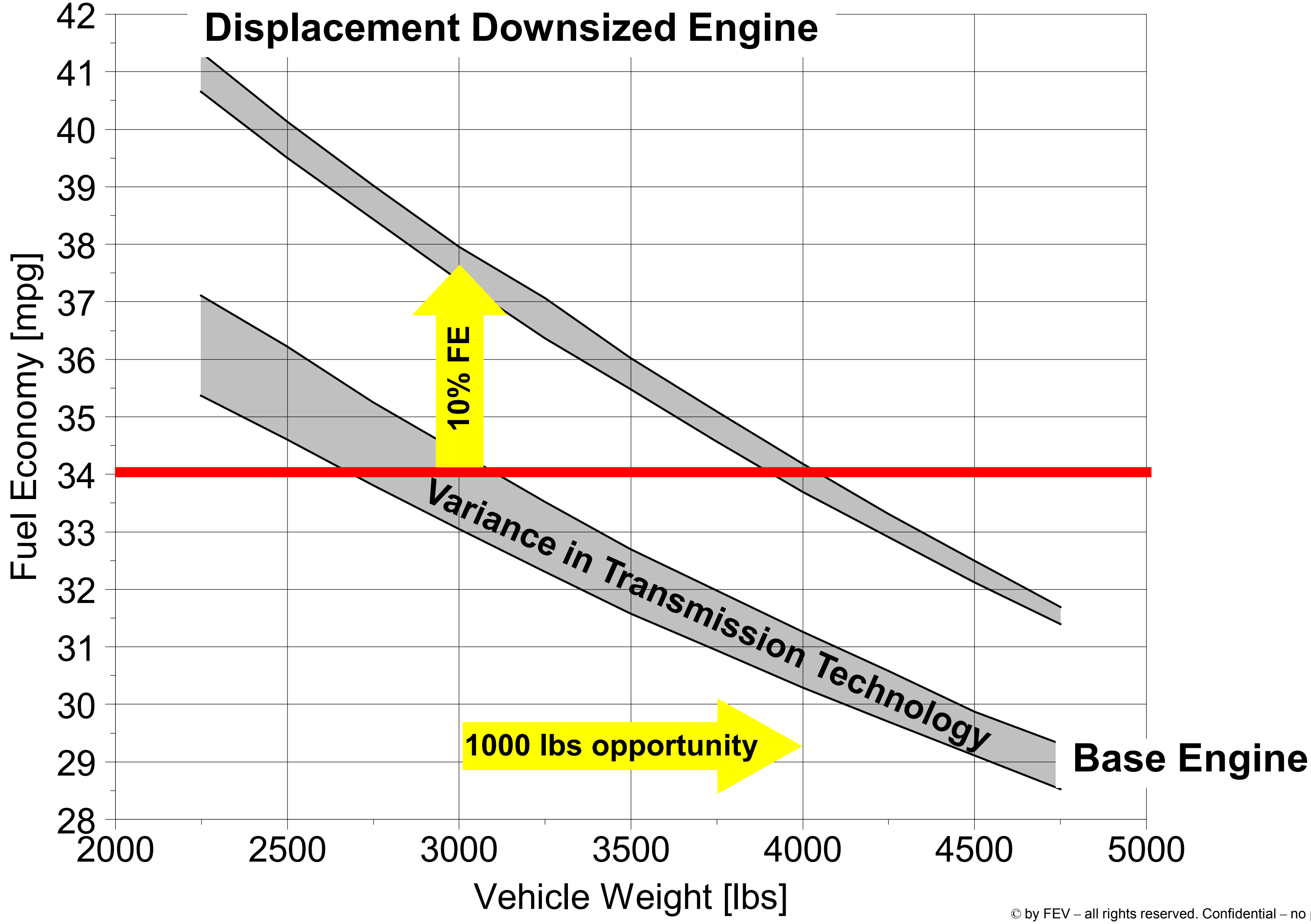
Future Directions in Engines and Fuels
Powertrain and Vehicle System Review

Final Thoughts



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Thank you

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