

Application of Synergistic Technologies to Achieve High Levels of Gasoline Engine Downsizing

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Ricardo**

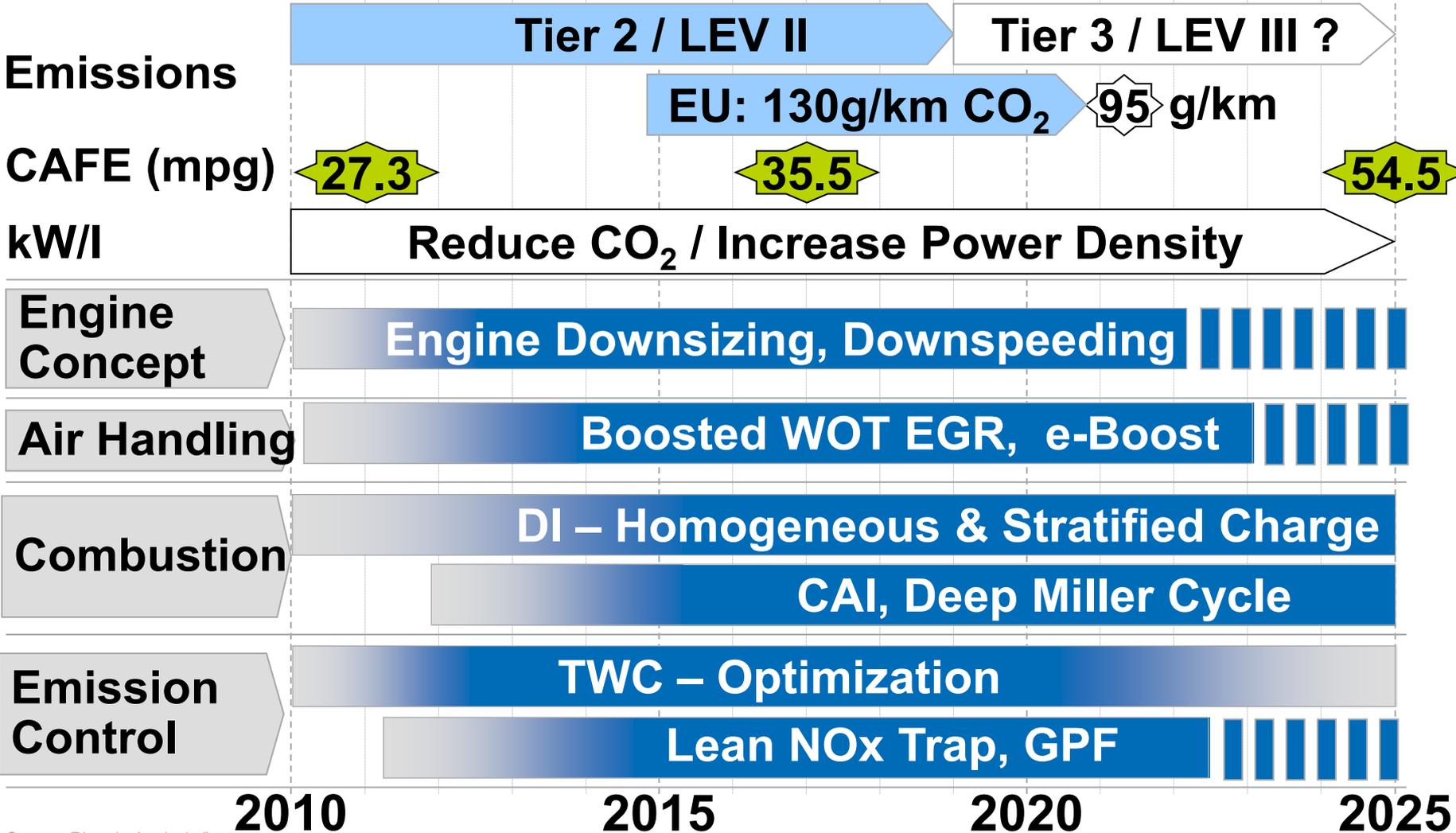
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Gasoline engine roadmap focus is on CO₂ reduction through downsizing



Technology Roadmap for Light Duty Gasoline

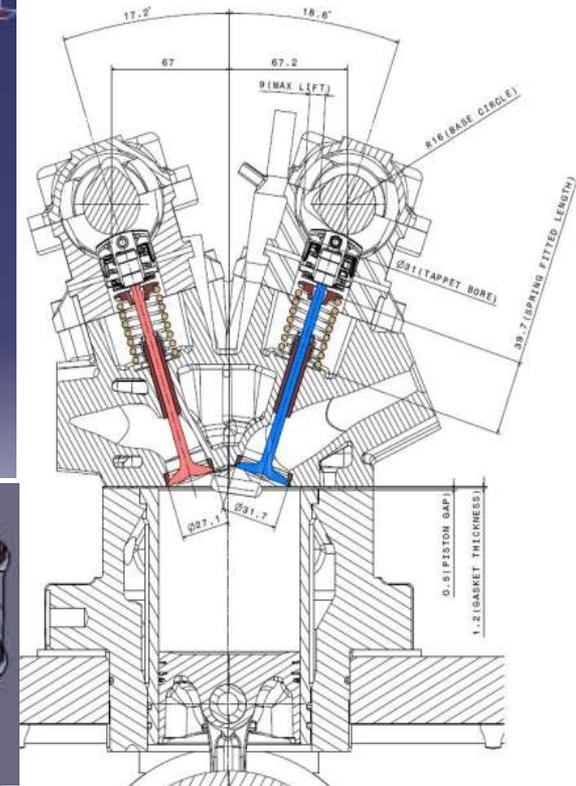
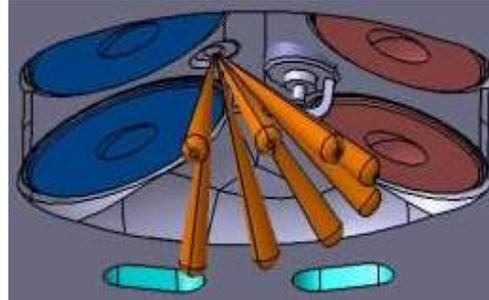
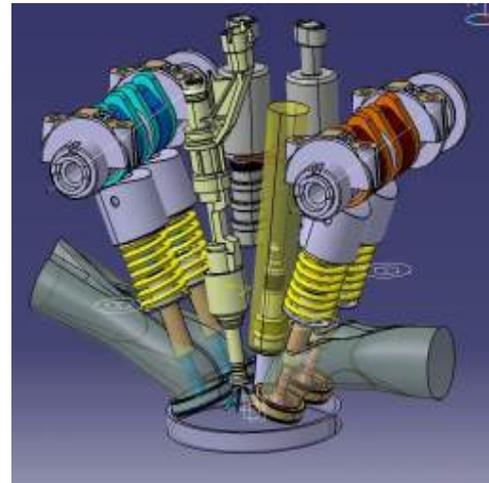


Source: Ricardo Analysis "

Spray Guided Direct Injection combustion systems are foundational to all engine pathways

Ideal requirements of GDI system

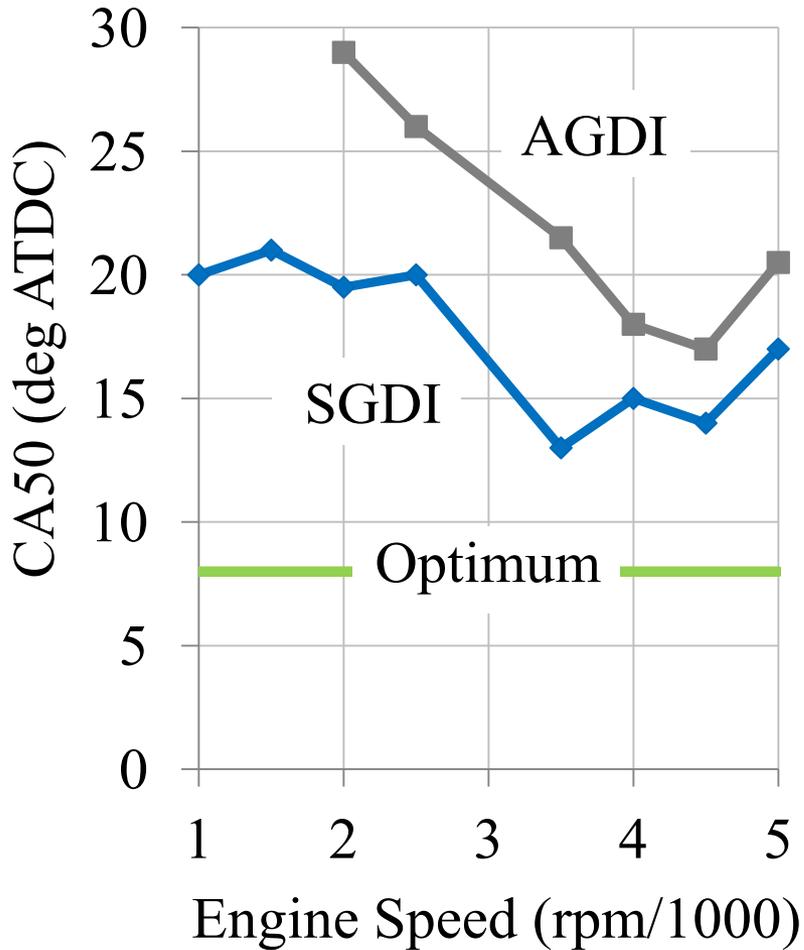
- Suitable for aggressively downsized engine design
- Low cost (solenoid injector)
- Flex-fuel capability
- Effective and durable stratified operation
- Support CAI operation
- Robust combustion at very high BMEP



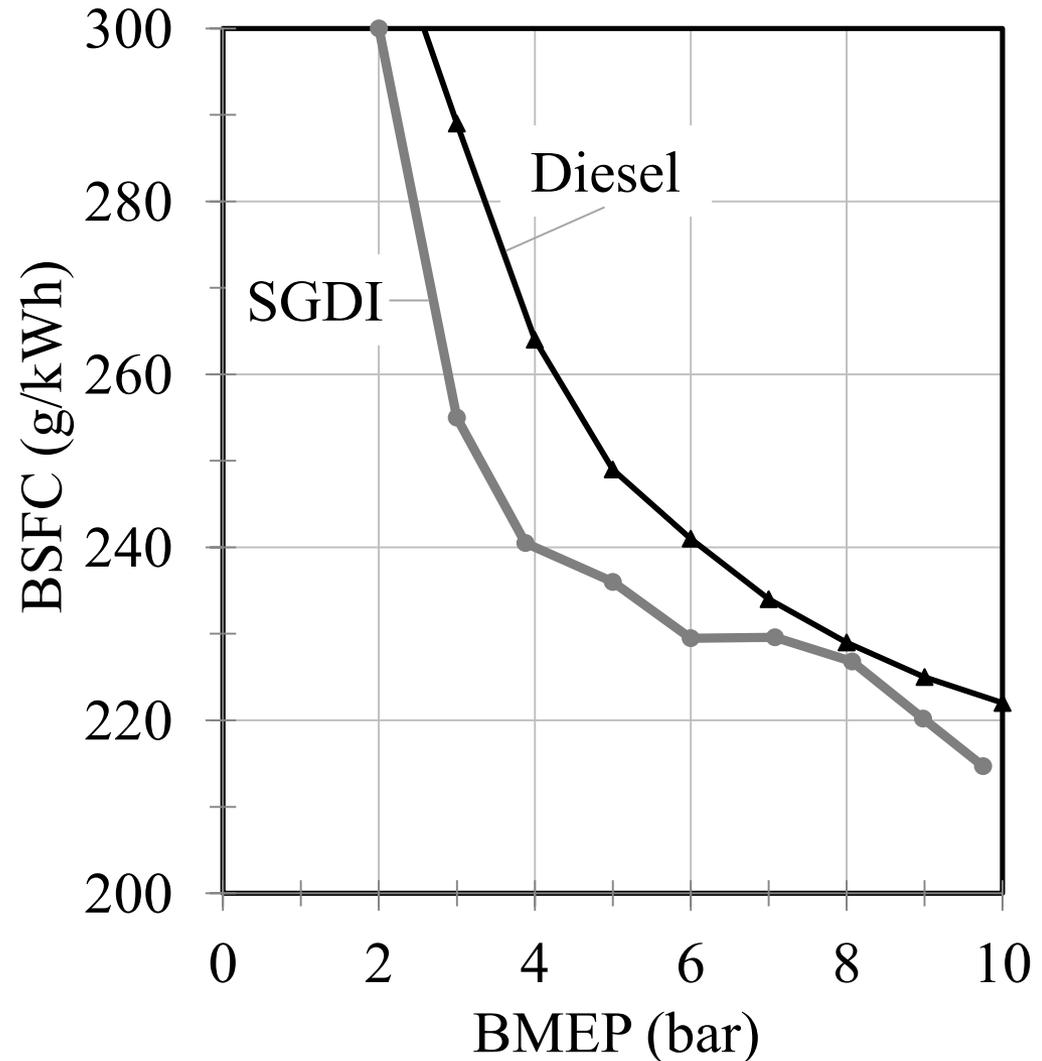
Stratified Boosted Engine Operation Achieves Ultra-Low Fuel Consumption



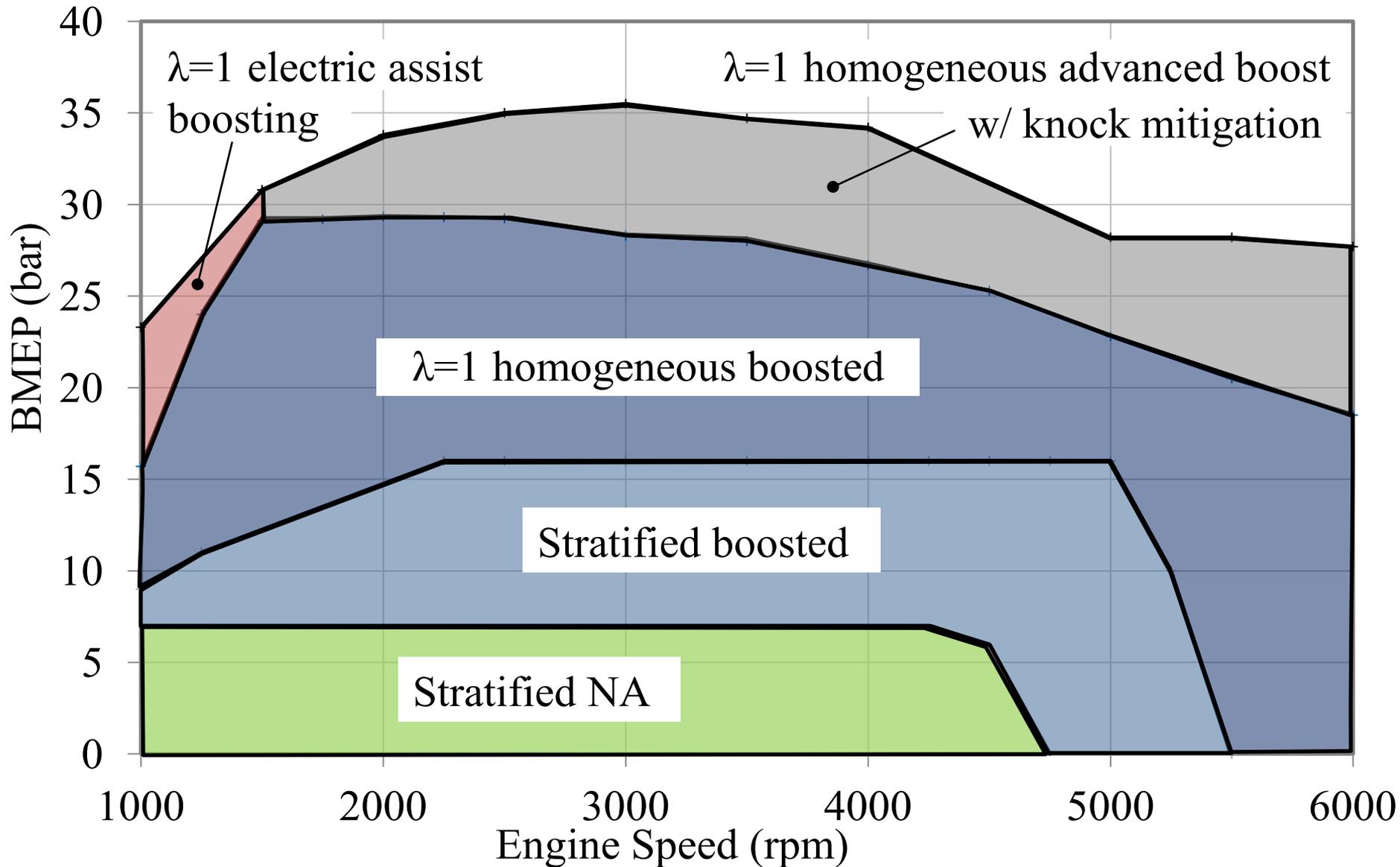
Combustion phasing at 18 bar BMEP



Fuel consumption at 2500 rpm



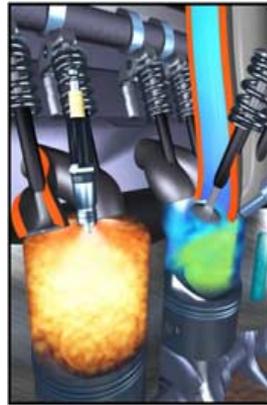
SGDI combined with advanced boosting and knock mitigation technology enables extreme torque curve



“HyBoost” features synergistic combination of downsizing , e-Boost, e-Turbine & iStop/Start

Downsized Gasoline Engine

- Downsized, highly boosted gasoline engine
- High load factor



E-Charger & E-Turbocompound

- E-charger for improved transient response
- High speed e-machine on turbocharger shaft



Low Cost Energy Storage

- 12V AGM Lead Acid battery
- Supercapacitors

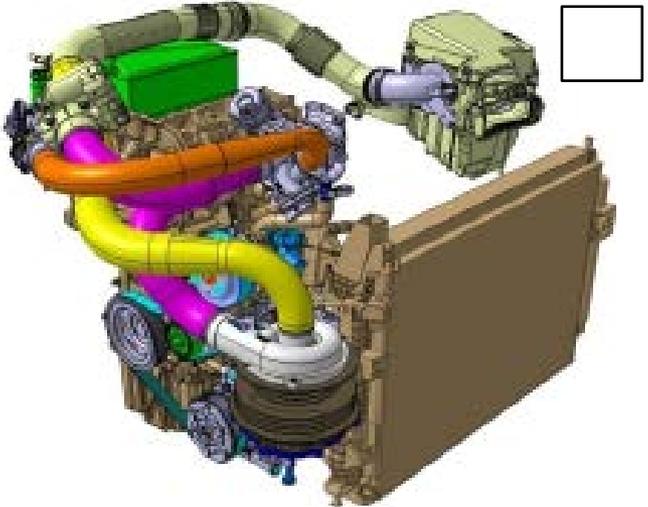
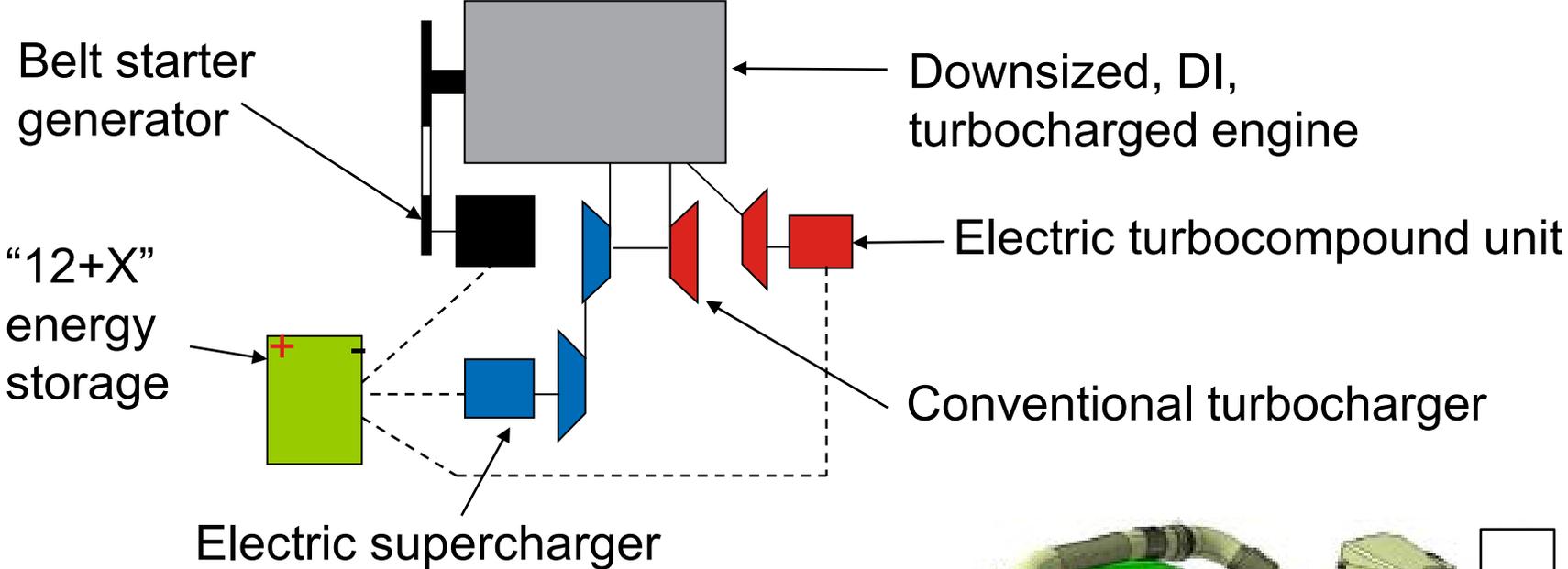


Micro-Hybrid

- 12+X e-machine
- Turbocompound electricity to crankshaft



HyBoost offers comparable performance to current 2-L variant but with fuel economy of a strong hybrid



HyBoost Performance Attributes & CO₂ Emissions



Vehicle	2.0L Duratec Ford Focus	Hyboost Focus	Toyota Prius
Max Power (kW)	107 @ 6000	105 @ 5500	73 @ 5200
Peak Tq (Nm)	185 @ 4000	240 @ 3500	142
0-62 mph (s)	9.2	9.2	10.4
31-62 mph (s)	11.9	11.2	tbd
Top speed (mph)	128	128	112
CO ₂ (g/km)	169	89 - 99	89

CO ₂ Emissions Reduction	
Base vehicle (2L Ford Focus)	169g/km
50% downsized 1L, Boosted DI, low friction	-25%
Stop-start & 6 kW regen	-10%
Cooled EGR, revised turbo match & e-boost	-6%
Taller gears + gearshift advisor	-7%
HyBoost vehicle emissions	99.7g/km

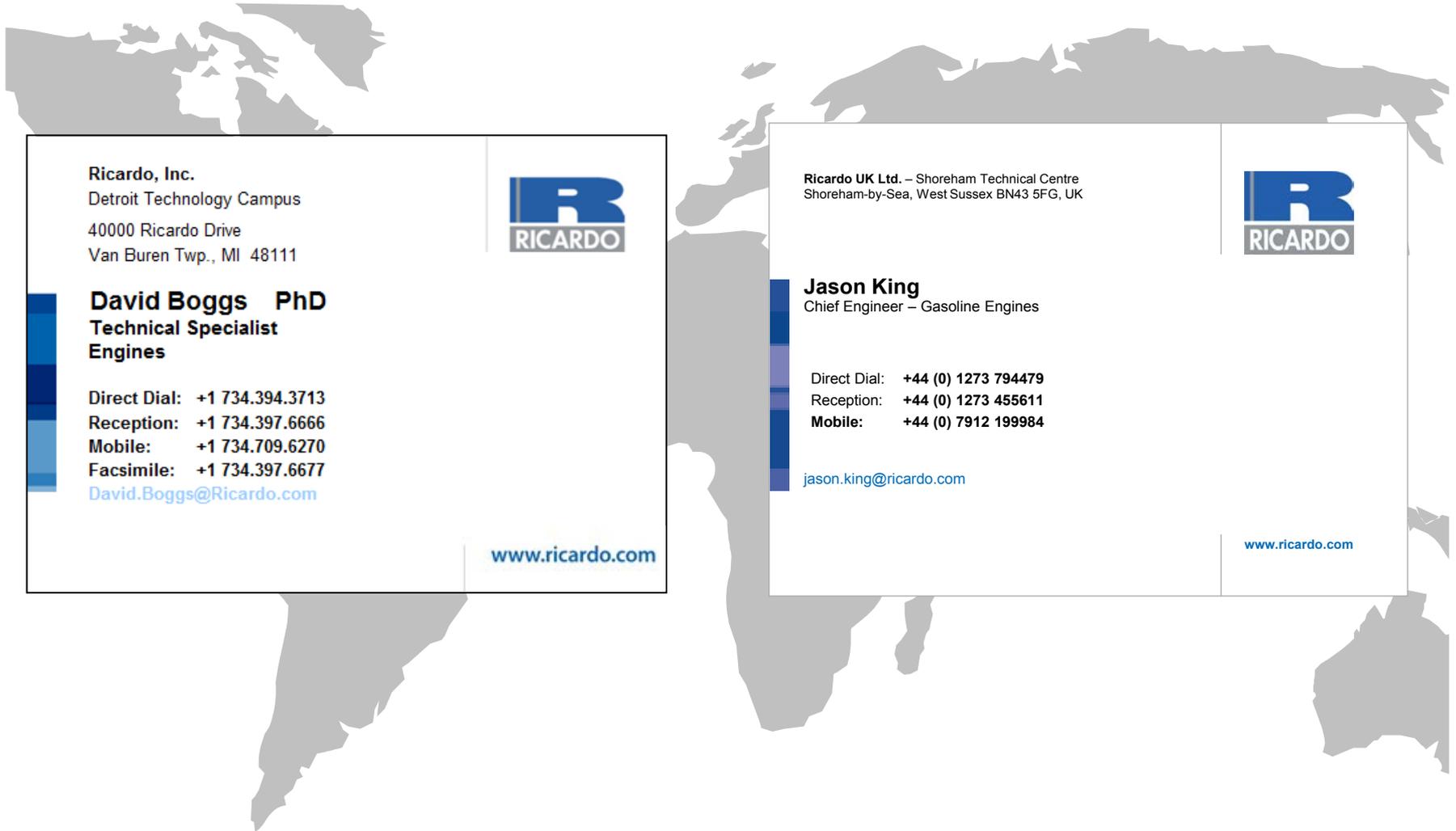
Summary & Conclusion

- Engine downsizing is central to Ricardo's roadmap for fuel economy improvements
- Next generation SGDI combustion system supports aggressive downsizing
 - Robust stratified engine operation with excellent fuel consumption
 - Highly tolerant combustion system
 - Knock mitigation technologies enable very high BMEP levels
- HyBoost vehicle demonstrates cost effective low CO₂ emissions potential

A grey arrow pointing downwards, centered below the list.

Application of synergistic technologies enables high levels of engine downsizing and vehicle fuel economy

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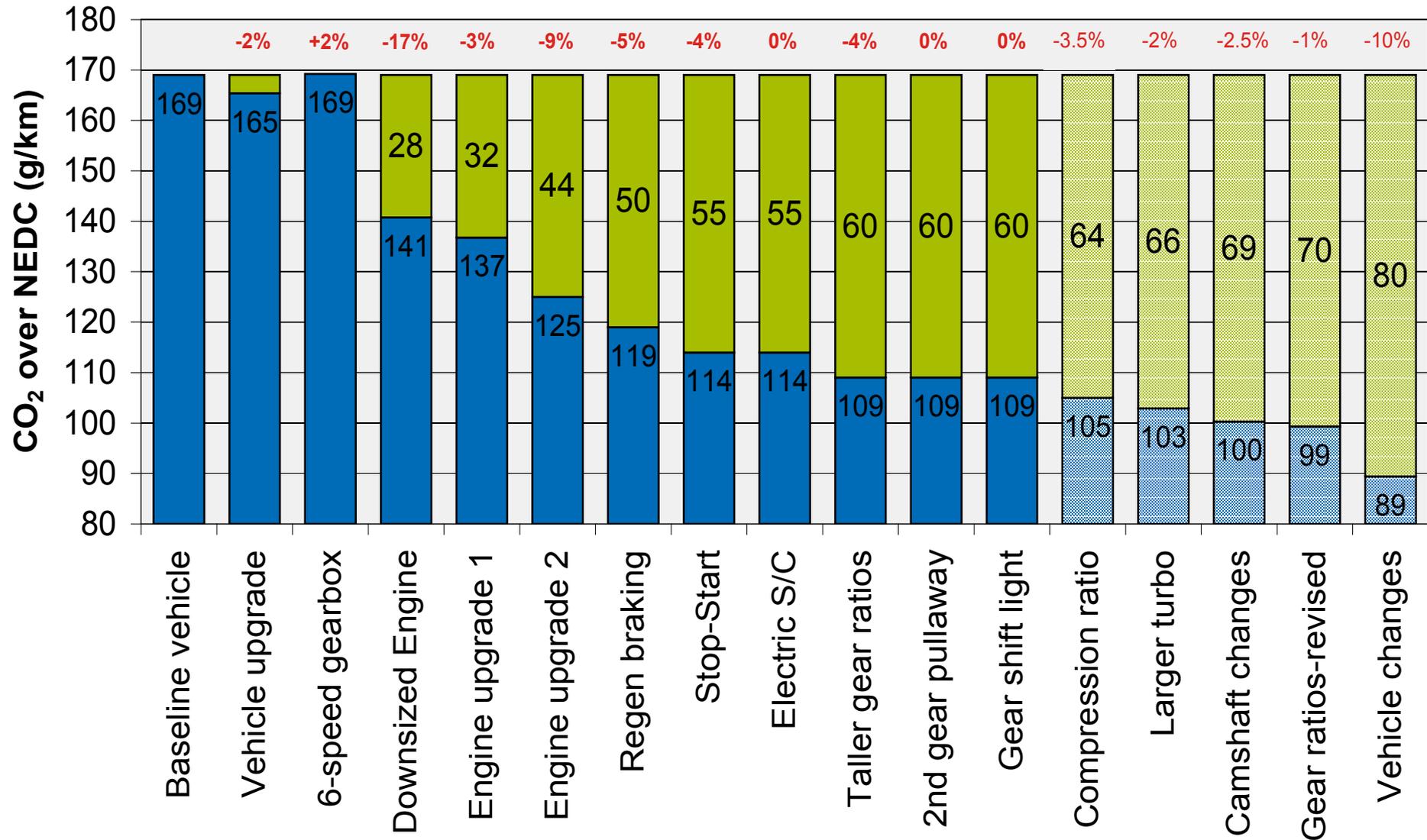
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C-class Vehicle CO₂ Glide Path to <95g/km



■ CO2 emissions over NEDC (g/km) ■ CO2 emissions reduction over baseline (g/km)



HyBoost system installation in Ford Focus



View from underneath engine bay

