Diesel Fuel Economy and CO_2 Challenge
Poster P-29

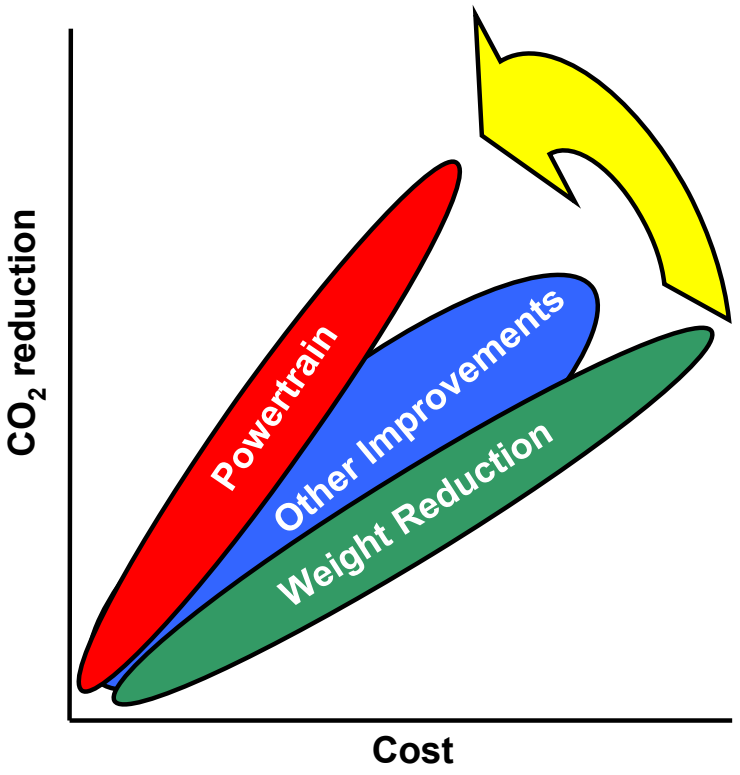
Mark Kuhn

Director – Light Duty Diesel Product Group

Ricardo

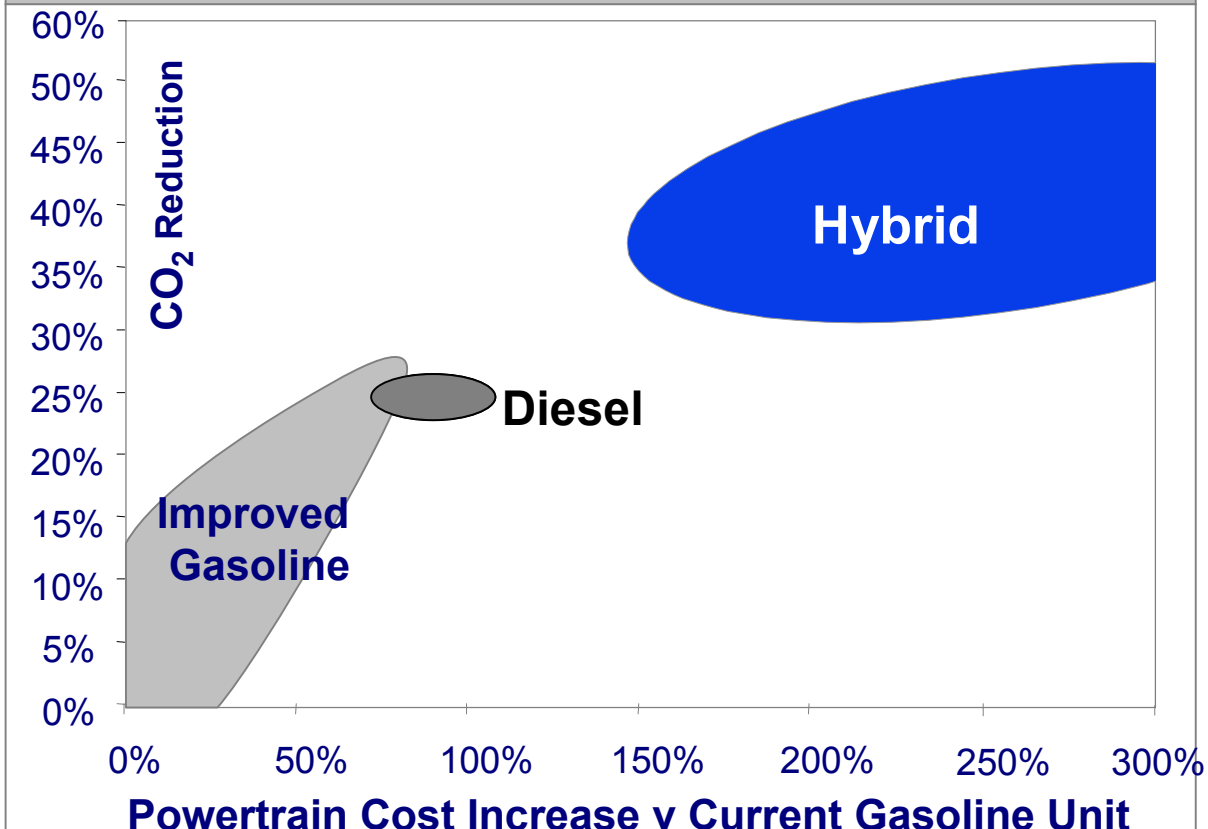
Powertrain improvements generally most cost-effective – New gasoline technologies close gap with diesel – Hybrid expensive

Cost/Benefit Ratio for CO_2 Reduction



Source: Ricardo Internal data

Cost vs. CO_2 Reduction for Powertrain Technologies

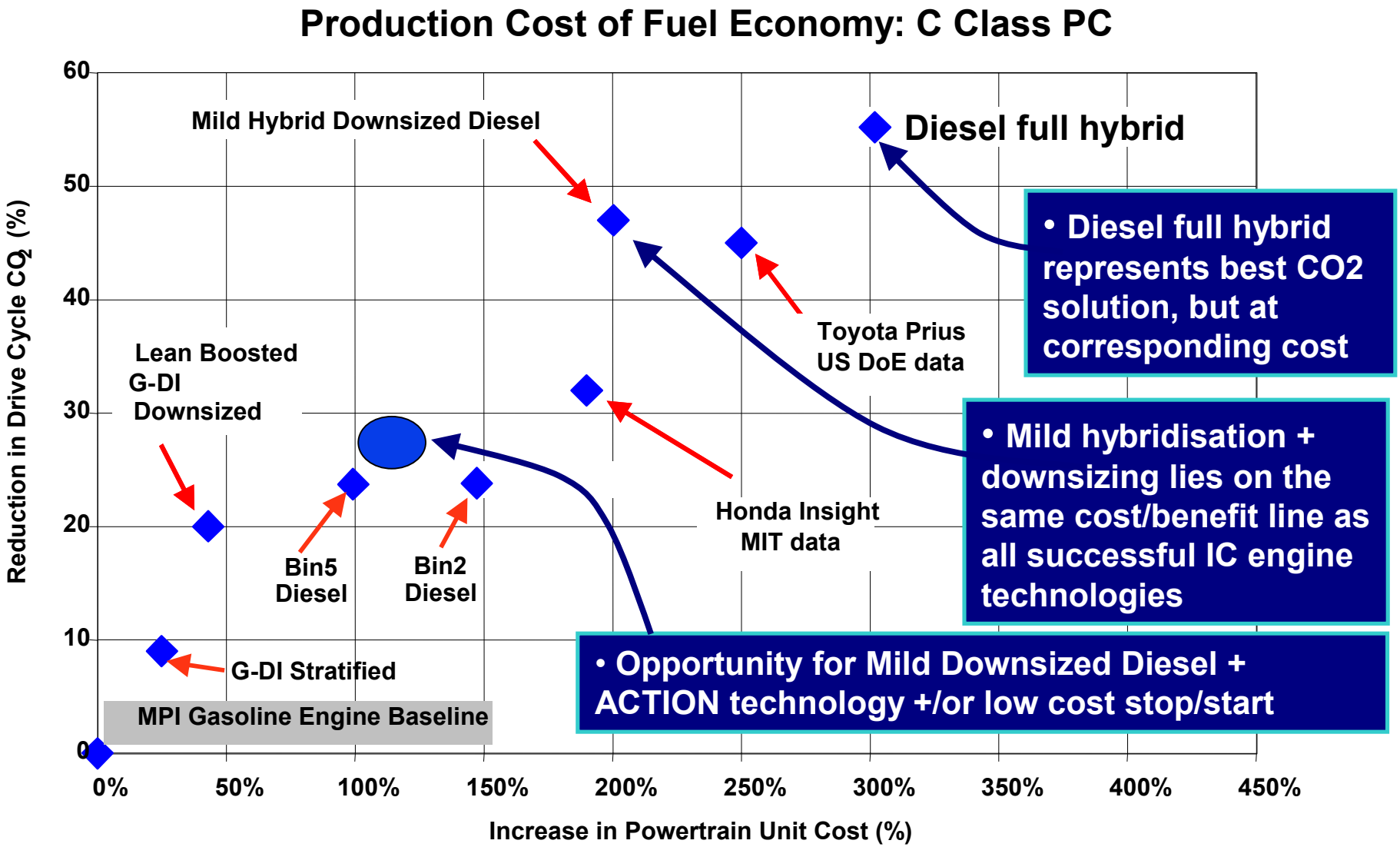


Source: Ricardo Internal data

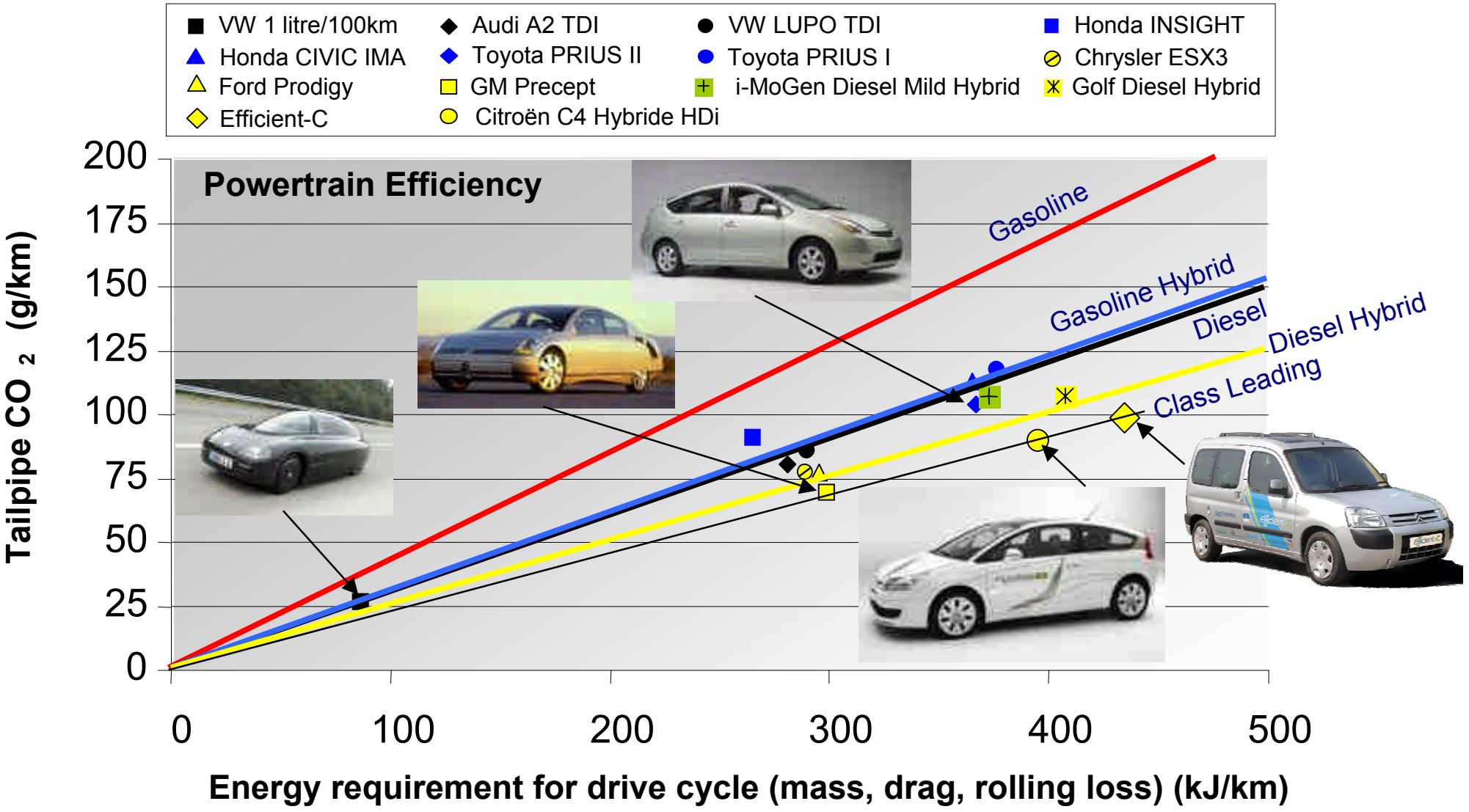
- Cost of weight reduction higher than powertrain improvements
- 10% reduction in weight delivers 5% cycle fuel economy

- Improvements in gasoline technology will close gap with diesel
- Hybrid systems expensive - less cost effective

Hybrid will have high cost impact. Opportunity exists for intermediate solution with minimum technology application



Comparison with Other Advanced Technology Vehicles shows Efficient-C has Class Leading Powertrain Efficiency



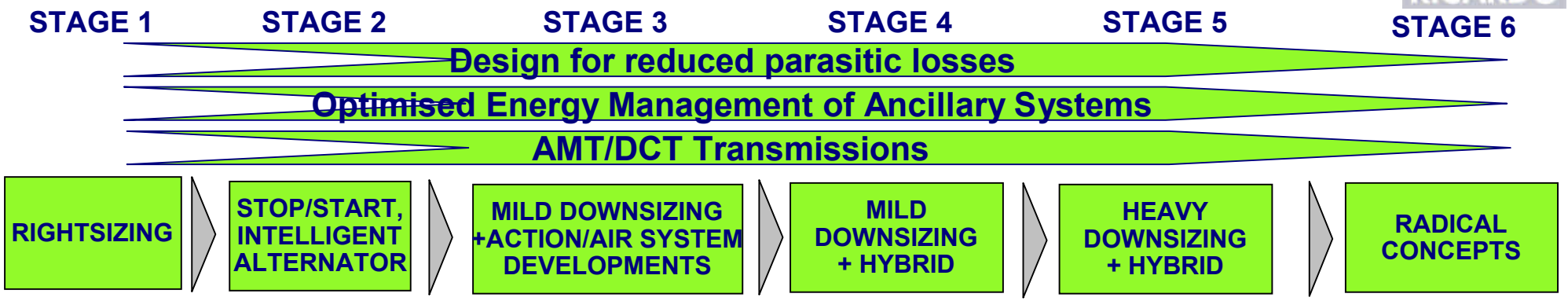
The challenge for diesel is to meet future emissions at minimum cost without compromising fuel economy advantage

New Diesel Technologies	Attributes						
	MPG	CO_2 Reduction	NOx Reduction	Particulate Reduction	Performance	Packaging	Cost
2-Stage Turbo	+	+	+	+	++	- -	- -
Advanced Single Turbo	+	+	+	+	+	+	-
Enhanced EGR	-	-	++	-	-	-	-
Low Temperature Combustion	-	-	++	+	/	/	-
Closed-Loop Control	+	+	+	+	+	/	-
DPF	-	-	+	+++	-	-	-
SCR	/	/	+++	/	/	- -	- -
Lean NOx Trap	- -	- -	++	/	/	-	- - -

- Engine technologies can enable emissions, fuel consumption and performance improvements
- New exhaust aftertreatment essential to meeting emissions requirements, especially in US
- DPF removes >95% of smoke and is now becoming standard in Europe and US

- ***Total system must be optimized to meet fuel economy, emissions, and performance at lowest cost***

Next steps for low CO_2 and low fuel consumption diesel engines



STAGE1: Right-sizing

- Product line-up with appropriate engine size for each application
- Optimize engine and technology selection
  - Lower rated variants should apply smaller engines not just de-rate
- Stop upsizing
  - Use base engine technology to enhance performance rather than larger engine

STAGE 3: BOOST TECHNOLOGY

- Mild downsizing enabled with low NOx technology
- Technology enablers
  - Electrical supercharging
  - Electrical assisted turbo
  - Mechanical supercharging
  - 2 stage boosting
  - Micro hybrid

STAGE 4-5: DOWNSIZED HYBRIDS

- Progressive application of hybridization to enable energy recovery and torque augmentation
- Heavy downsizing
- Parallel application of improved energy management of engine and vehicle systems

STAGE 5: R&D TECHNOLOGY

- Plug-in hybrid
- Exhaust energy recovery
- Radical structures
- Advanced battery technology
- Plasma & fuel reformers

EVERY DESIGN PARAMETERS CAN BE ACCESSED BY THE OPTIMIZER

Advanced Fuel Economy Tool

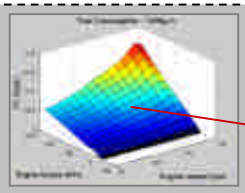
Engine

Friction

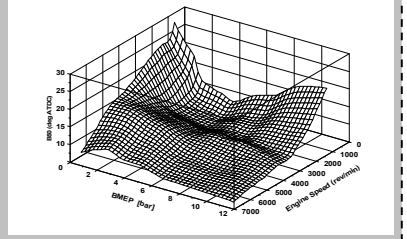
- Crankshaft Friction
- Balancer Drive Friction
- Power Cell Friction
- Camshaft Friction
- Valve train Friction
- Front End Drive Friction
- Oil Pump Friction
- Water Pump Friction
- Accessory Drive Friction
- Other Technology Effects

FAST
Databases
Papers
RS Valdyn, etc…

BSFC maps



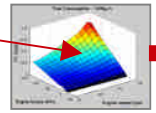
Databases
I4, V6, V8, etc…
Diverse fuel, NA, Turbo



Technology Modifier maps

Coefficient maps to apply to base BSFC map or additional maps to integrate advance technology:
VVT, VVA, Turbocompound, etc…
Database, Papers, WAVE

Look Up Map [FEAD, etc…]



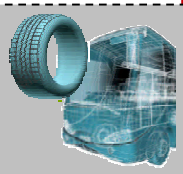
Custom Fuel Maps

Transmission

- Type of gears
- Number/type of seals
- Number/type of bearings
- Number/type of clutches
- Wet/Dry Sump, etc…

Excel/Test:
- ❑ MT
- ❑ AT
- ❑ CVT
- ❑ DCT
- ❑ etc T…

EASY5 PARAMETERS

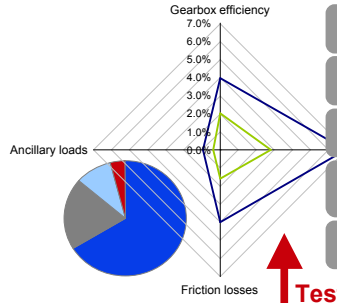


Vehicle

- Tire / Rolling Resistance
- Drag Reduction
- Cooling System
- Interior Feature
- Exterior Features, etc…

Database Simulation [AMESim, Flowmaster]
Papers

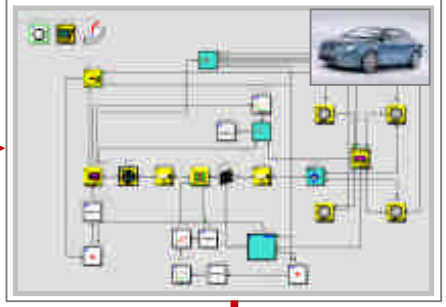
Trade Off Analysis



- Fuel Economy
- Acceleration & Performance
- Gradeability
- Hybrid Post-Processor Start/Stop, Regen Capacity…
- Driveability

Test Results

Core Vehicle Model



Test Results

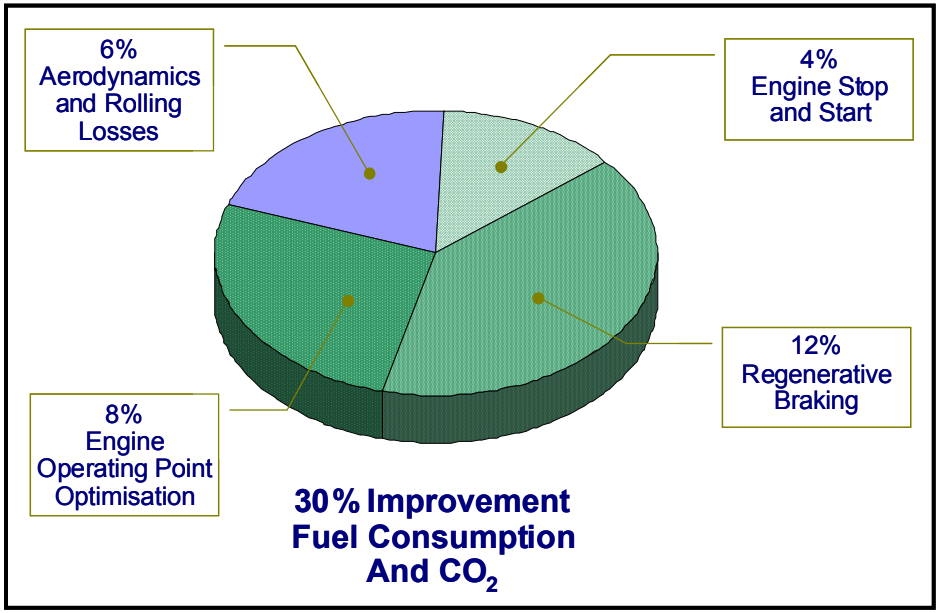
DART
Driveability Assessment and Rating Tool

Case Study: Project Achievements

- 30% improvement in fuel consumption and CO2 emissions relative to current state-of-the-art diesel vehicle
  - 99g/km CO2 in Berlingo
  - 90g/km in C segment saloon
- Euro IV emissions over NEDC, plus addition of Particulate Filter

VEHICLE	Berlingo Multispace	Efficient-C
Engine	Diesel 1,6L (66kW)	Diesel Full-Hybrid
Performance (with half of maximum payload)		
Maximum speed	158kph / 99mph	171kph / 106mph
0 - 100 km/h (s)	14.8	13.4
0 - 1000 m (s)	36.6	35.5
30 - 60 km/h (s) ***	5.6	4.6
80 - 120 km/h (s) ***	17.9	12.3
NEDC Cycle		
Fuel consumption Urban*	6.7 l/100km, 42 mpg	3.7 l/100km, 76 mpg
Fuel savings Urban	reference	45%
Fuel consumption Extra-Urban*	4.7 l/100km, 60 mpg	4.0 l/100km, 71 mpg
Fuel savings Extra-Urban	reference	15%
Fuel consumption Combined**	5.4 l/100km, 52 mpg	3.75 l/100km, 75 mpg
Fuel savings Combined	reference	30%
CO_2 emissions	143 g/km	99 g/km
CO_2 reduction	reference	30%

* SOC neutral operation in each phase ** SOC neutral over combined cycle
*** Fixed gear ratio for the reference vehicle. On the Efficient-C vehicle, a kick-down is included



- Uncompromised performance, comfort and interior space
- Zero Emissions operating mode for sensitive urban environments
- Estimated additional cost of £3,000 over conventional diesel vehicle