

**MAHLE**

*Powertrain*

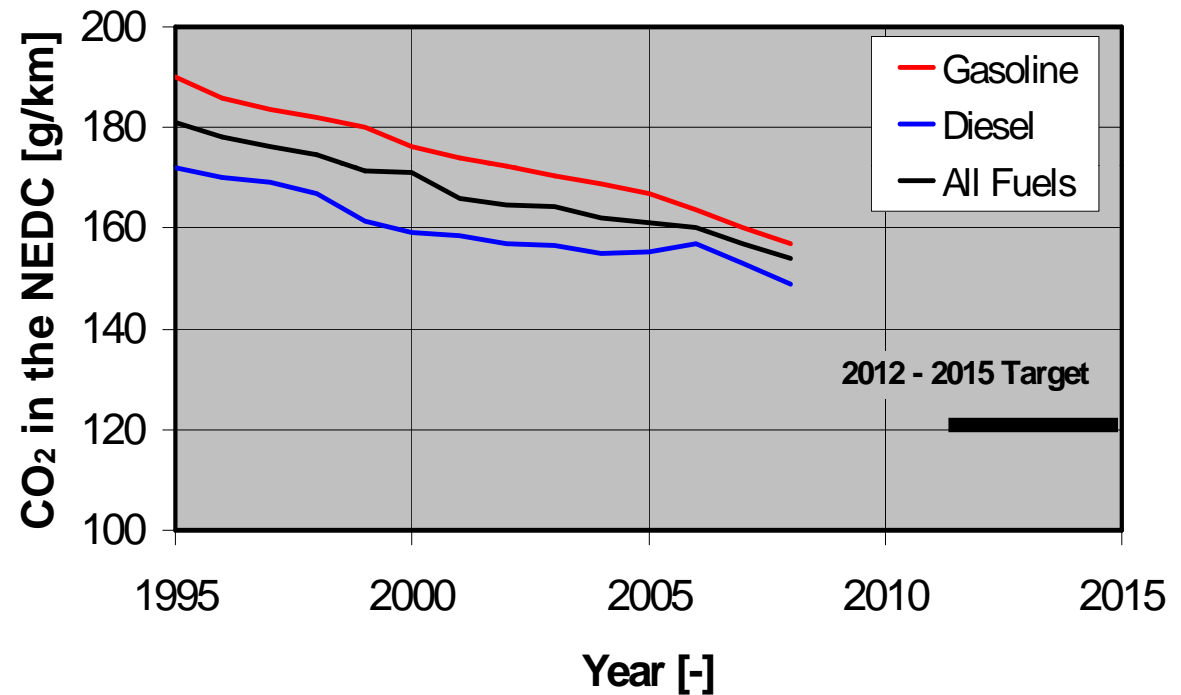
## High Efficiency Engines for Emerging Markets

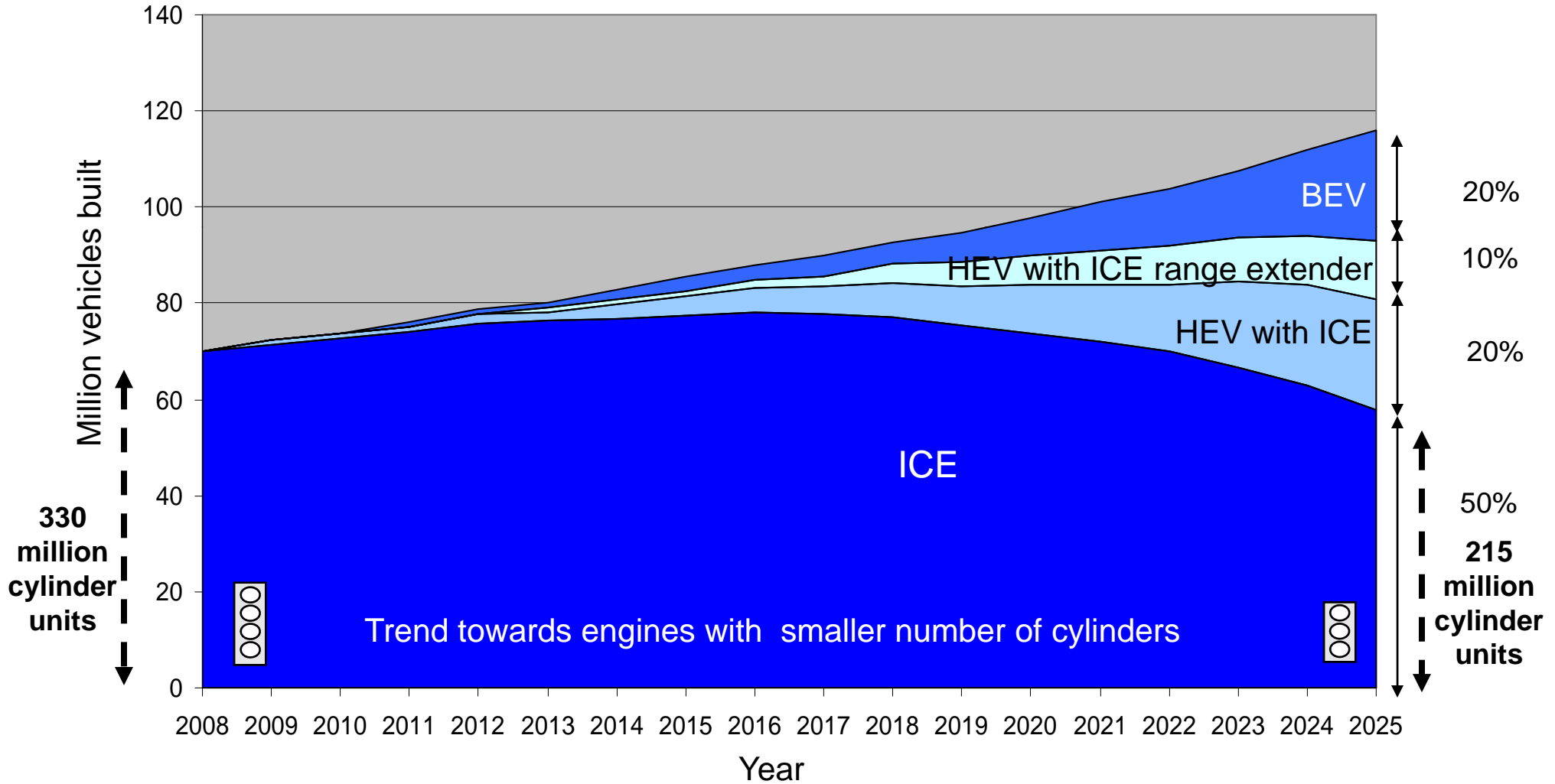
Presentation at  
UKTI India Low Carbon Vehicle Mission  
New Delhi, November 25<sup>th</sup>, 2009

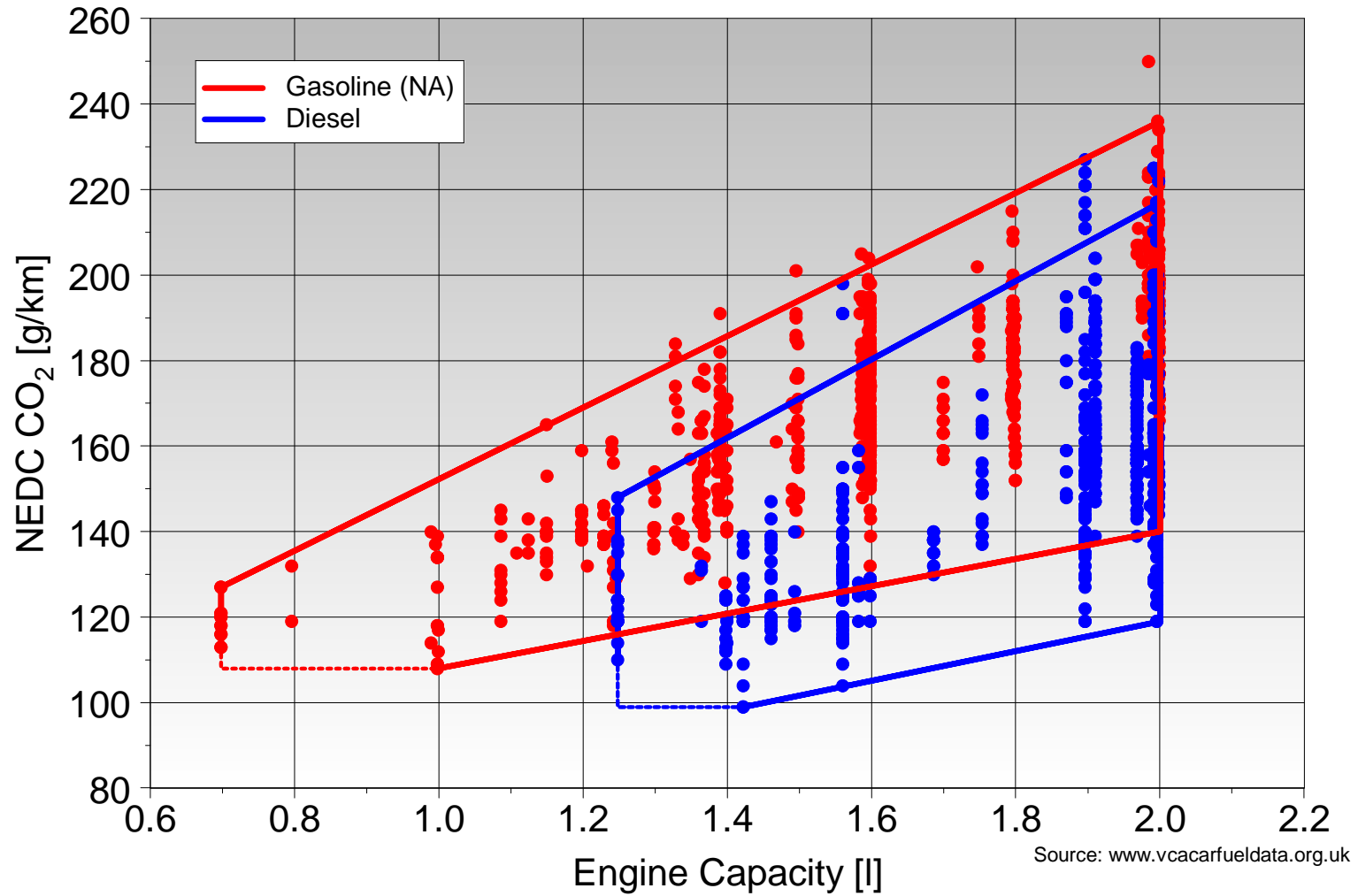
Volker Korte



- Fuel consumption improvement has become the main driver in engine development
  - to save raw oil resources
  - to meet the CO<sub>2</sub> emission targets
- Current trend from new car registrations shows continuous CO<sub>2</sub> emission improvement for the last decade







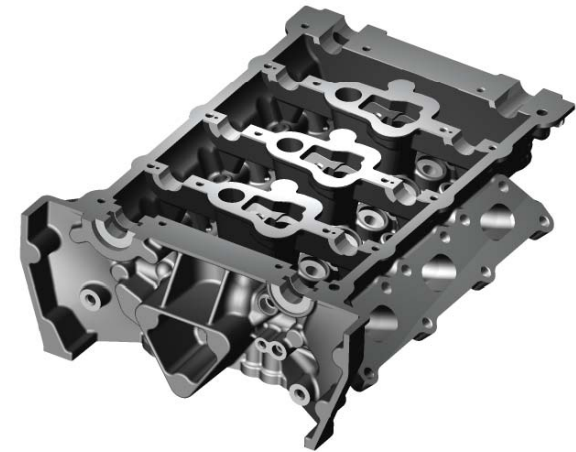
- Displacement
- Weight
- Transmission

## Approach

# High Efficiency Engine for Emerging Markets Base Engine

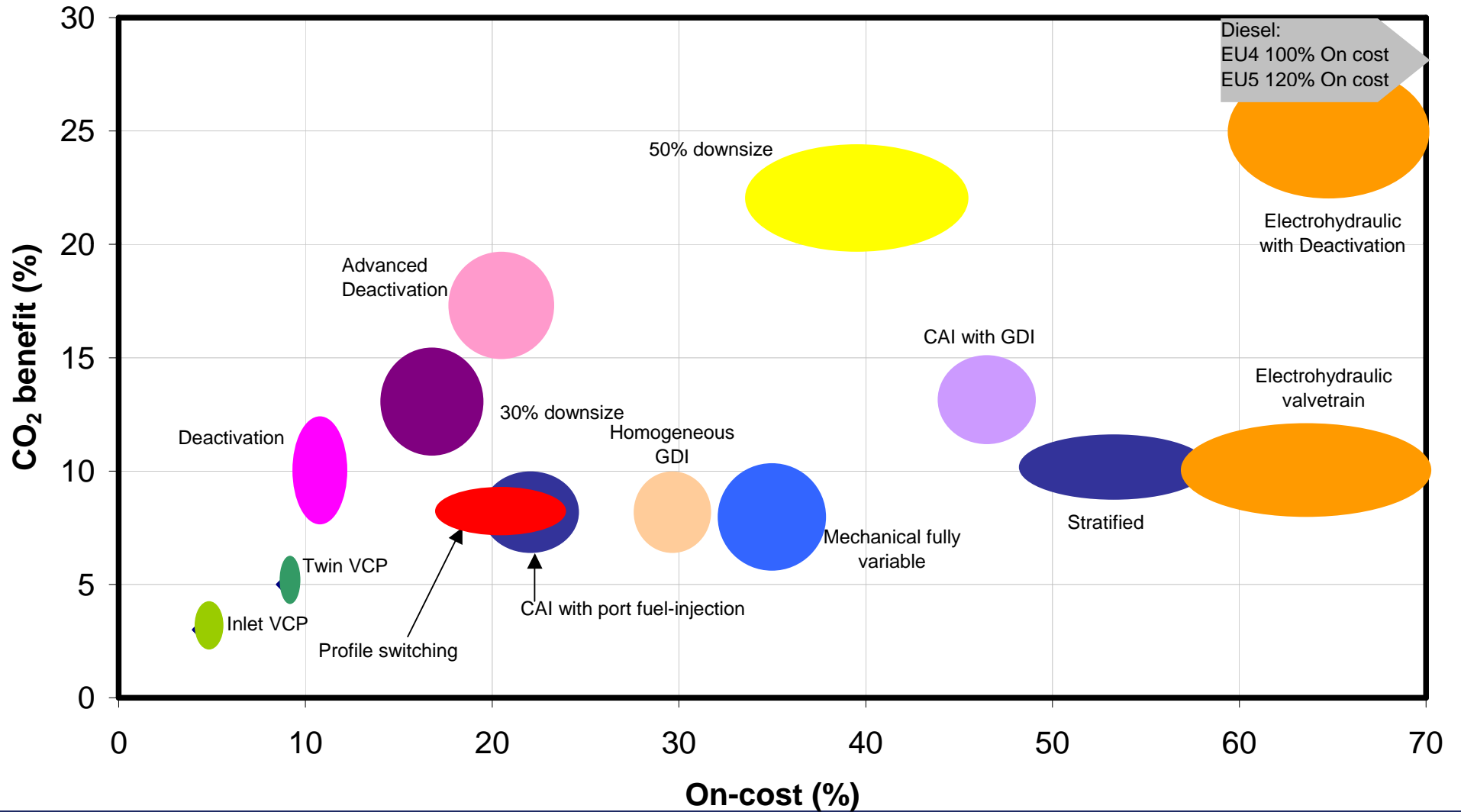


- Low Cost → Focus on Gasoline engines
- Optimum thermodynamic engine is achieved with a cylinder displacement  $V_h = 0.3 - 0.4$  l
- Low friction is achieved with a lower number of cylinders
- Cylinder displacement of  $V_h = 0.3 - 0.4$  l results with a 3-Cylinder engine in an engine displacement of  $V_H = 0.9 - 1.2$  l
- Combines high fuel economy and good driving performance
- Baseline for a family concept with
  - N/A and turbocharged versions
  - additional 2 and 4 cylinder versions (2 cylinder also for range extender)



# Approach

## High Efficiency Engine for Emerging Markets Technology Options



## Approach

# High Efficiency Engine for Emerging Markets Technology Selection for Base Engine



- 4 valves/cylinder (for future flexibility)
- Port fuel injection, but design protected for gasoline direct injection
- Aluminium block for low weight
- VVT (intake)
- Low friction valve train (roller finger follower)
- Low friction power cell unit (PCU)
  
- Detailed initial analysis for the optimum between WOT characteristic (expected driving performance) and vehicle fuel economy including vehicle parameters (weight, transmission)



Base Engine

- 55 kW/l

Performance Option

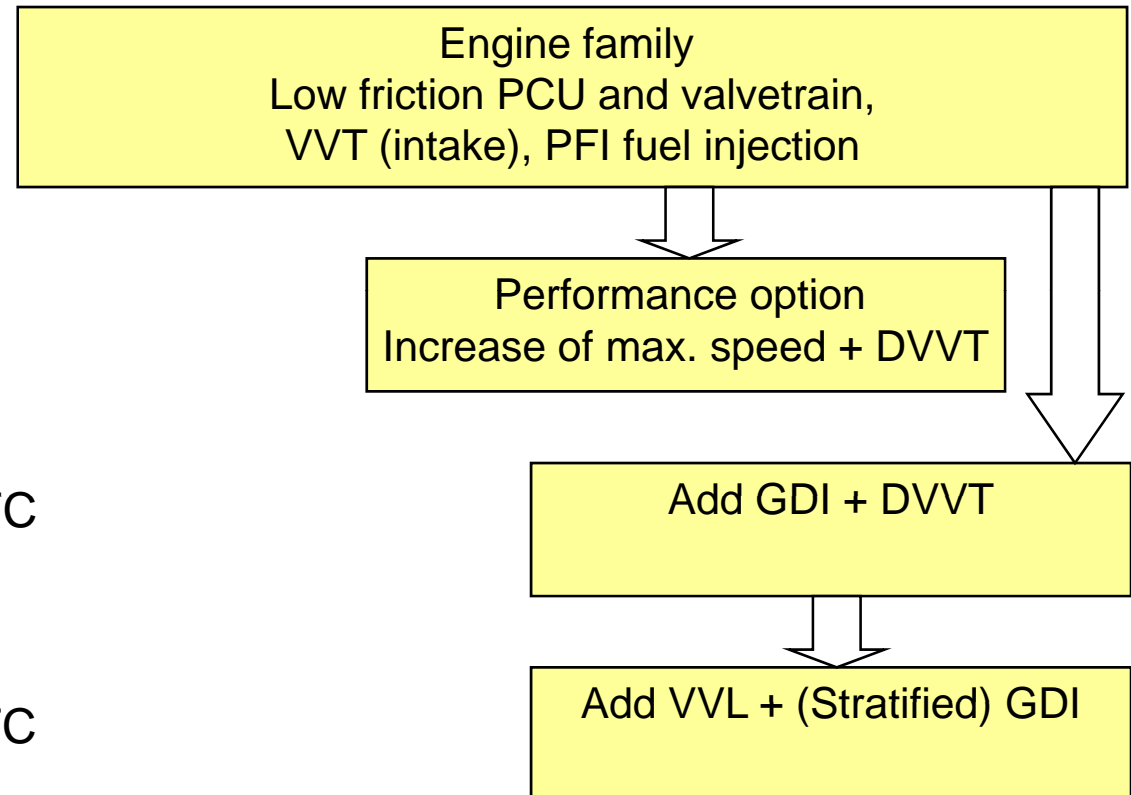
- 62 kW/l

Economy Option

- ~10% improvement in vehicle FC

Economy Option 2

- ~15% improvement in vehicle FC



Detailed definition of all options needed during initial engine family planning

Base Engine

- 55 kW/l

Turbo Option

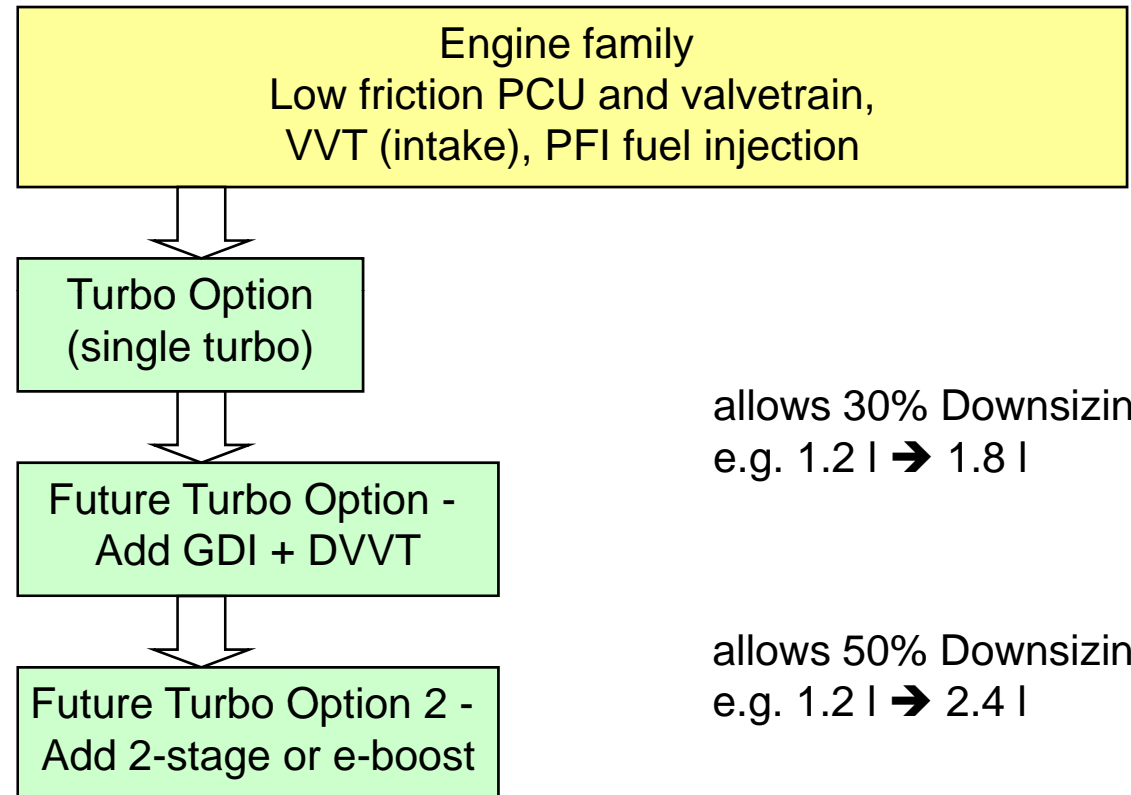
- 90 kW/l

Future Turbo Option

- 100 kW/l

Future Turbo Option 2

- 120 kW/l



allows 30% Downsizing  
e.g. 1.2 l → 1.8 l

allows 50% Downsizing  
e.g. 1.2 l → 2.4 l

Detailed definition of all options needed during initial engine family planning

## Advanced Technology Options Further Friction Optimisation

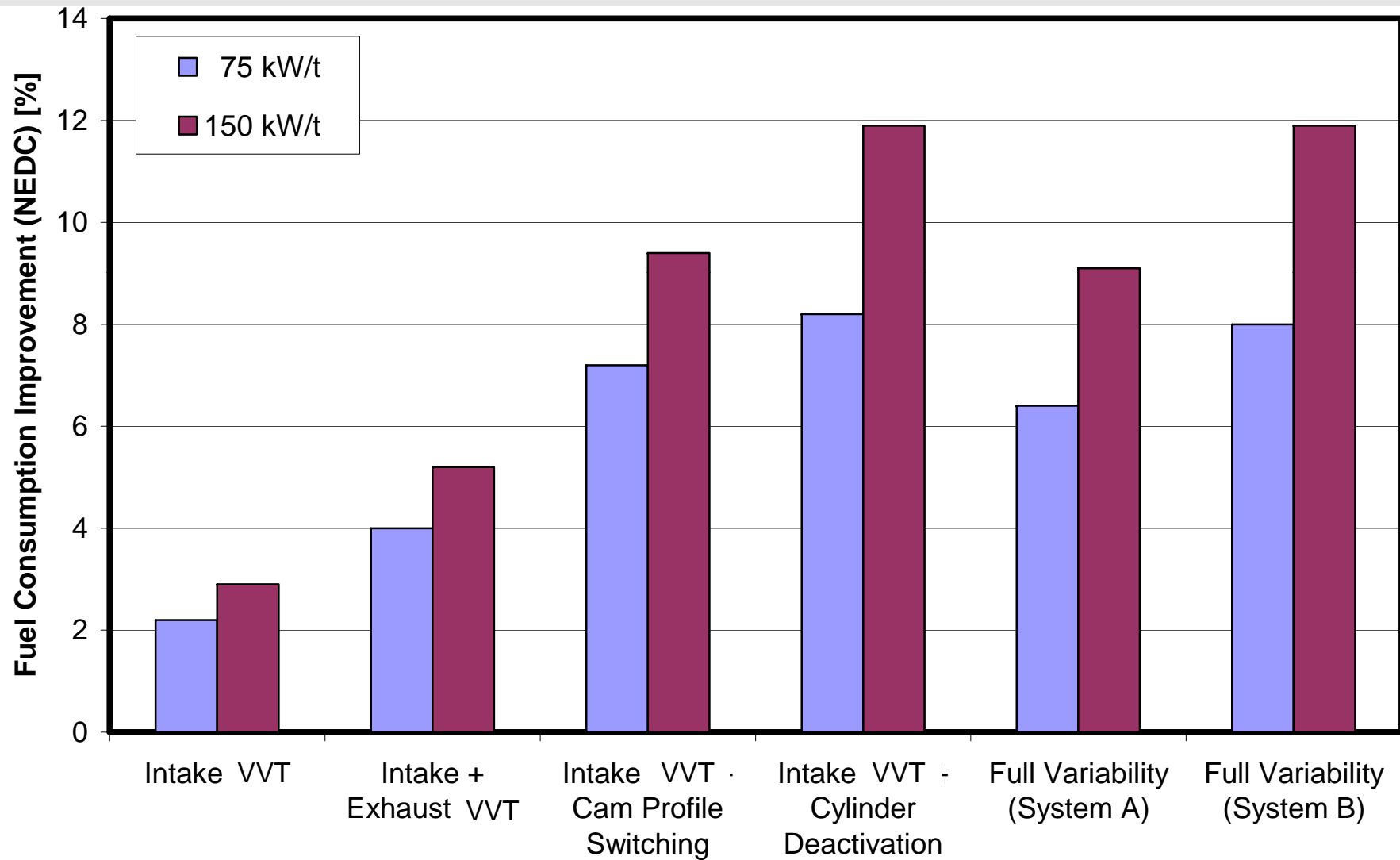


- MAHLE have invested heavily in low friction engine technologies – applicable to all engine sizes
- Demonstrator engine was designed to incorporate new technologies
  - Roller bearing camshaft
  - Lightweight valves & optimized valve springs
  - Steel MONOTHERM<sup>®</sup> pistons with optimized ring pack and PVD coated top ring
  - New crankshaft with reduced big end bearing areas
- Vehicle tests demonstrate 3% improvement in fuel economy over NEDC

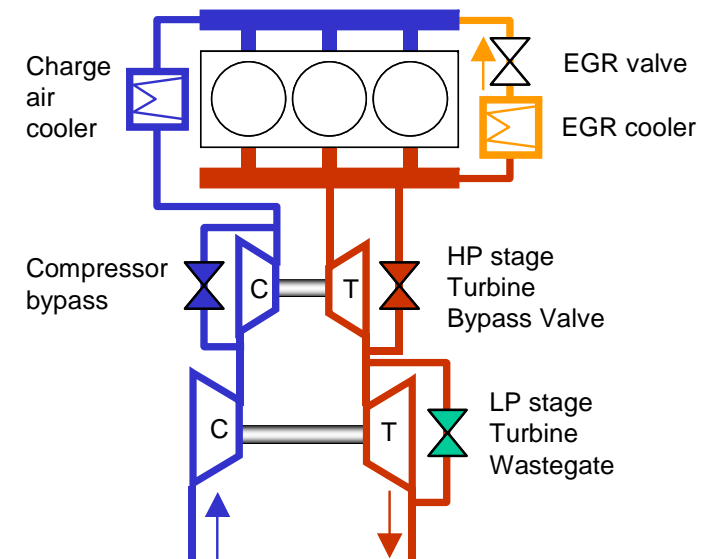


# Advanced Technology Options

## Variable Valvetrain Systems

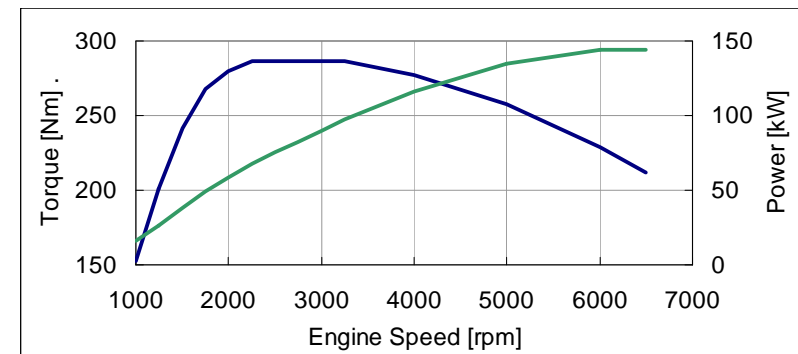


- Gasoline 'Variable Geometry Turbocharging' for improved low speed torque
- MAHLE CamInCam (Exhaust VVT 'Torque Boost') for improved low speed torque
- High-load EGR for reduced high-load & high speed fuel consumption
- Water cooled exhaust manifolds as an enabling technology
- Two-stage turbocharging for SI engines
- Twin scroll turbochargers for SI engines
- Electric compressor
- Vehicle cooling and heat management are critical considerations for any boosting concept (e.g. split cooling)



# MAHLE Downsizing Engine Two-stage Turbocharging and GDI

- 50% downsized concept DI-3 1.2 l
  - 30 bar BMEP
  - 120 kW/l
- Shows the potential for future production engine combustion and boosting systems
- > 30% vehicle CO<sub>2</sub> reduction possible compared to NA engine with similar performance levels
- Low speed torque and transient response are key
- Currently a research tool for MAHLE group and selected partner programs
- Vehicle demonstrators currently planned for 2010 (also for 30% downsizing)
- Key technology for CO<sub>2</sub> reduction



- Base engine (gasoline) with 3 cylinder for  $V_H = 0.9 - 1.2$  l engine displacement and
  - Port fuel injection, but design protected for gasoline direct injection
  - VVT (intake)
  - Low friction valve train (roller finger follower)
  - Low friction power cell unit (PCU)
- Family approach with
  - N/A and turbocharged versions
  - additional 2 and 4 cylinder versions (2 cylinder also for range extender)
- Advanced technology options for
  - Further reduced engine friction
  - Variable valve timing
  - Boosting concepts

**MAHLE**

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**Thank you very much for your attention !**

