FPC2014

Heavy Duty Dual-Fuel Engines

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Steve Whelan
Clean Air Power
swhelan@cleanairpower.com

CLEAN AIR POWER

Introduction

- The technology delivers 20% fuel cost saving and carbon reductions
- Originating in 1980's California, CAP has pioneered Dual-Fuel technology to enable Heavy Duty Trucks to operate on natural gas & diesel
- 70 patents (granted & pending) and over 30 years of Dual-Fuel experience
- Publically owned on the London Stock Exchange (AIM:CAP)
- Only developer of Dual-Fuel technology to supply OEM on-line assembly

Over 2500 vehicles in operation in Europe, N America, Asia & Australia


USA 430 HP US2010
GENESIS VOLVO &
MACK MP813


AUSTRALIA 460 HP EURO 5
GENESIS VOLVO FH13

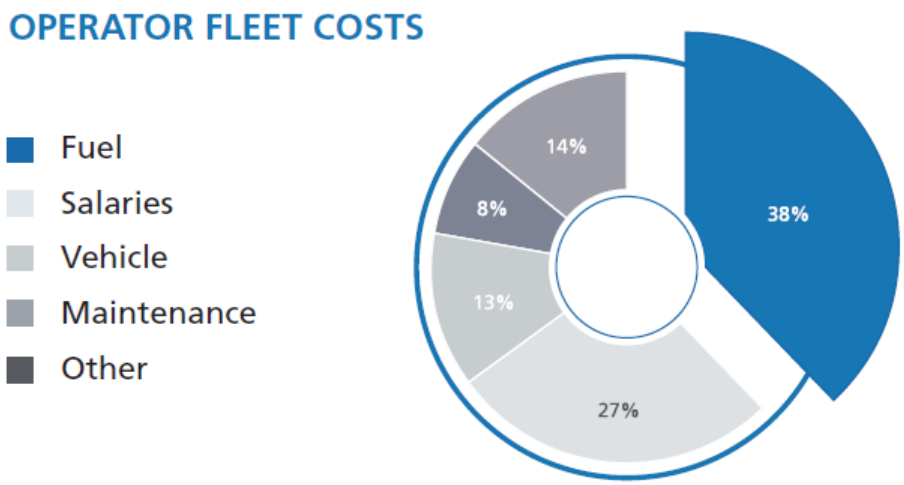

USA 410 HP
CATERPILLAR C-12


UK 460 HP EURO 5
GENESIS VOLVO FM13


USA & AUSTRALIA 500 HP
CATERPILLAR C-15

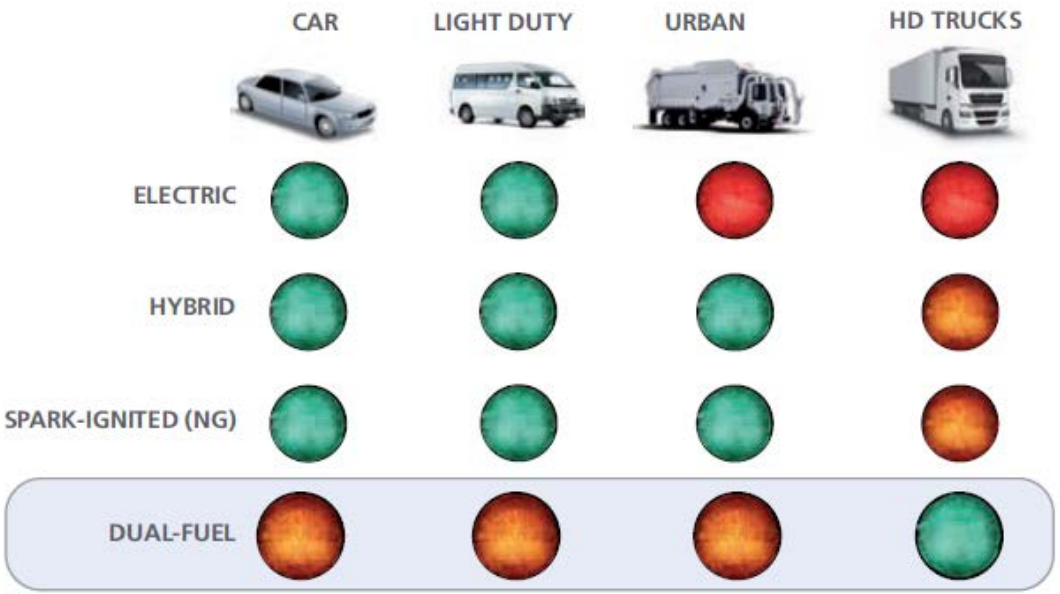

SPAIN 480 HP EURO 5
GENESIS RENAULT MAGNUM

Dual-Fuel Target Market Segment



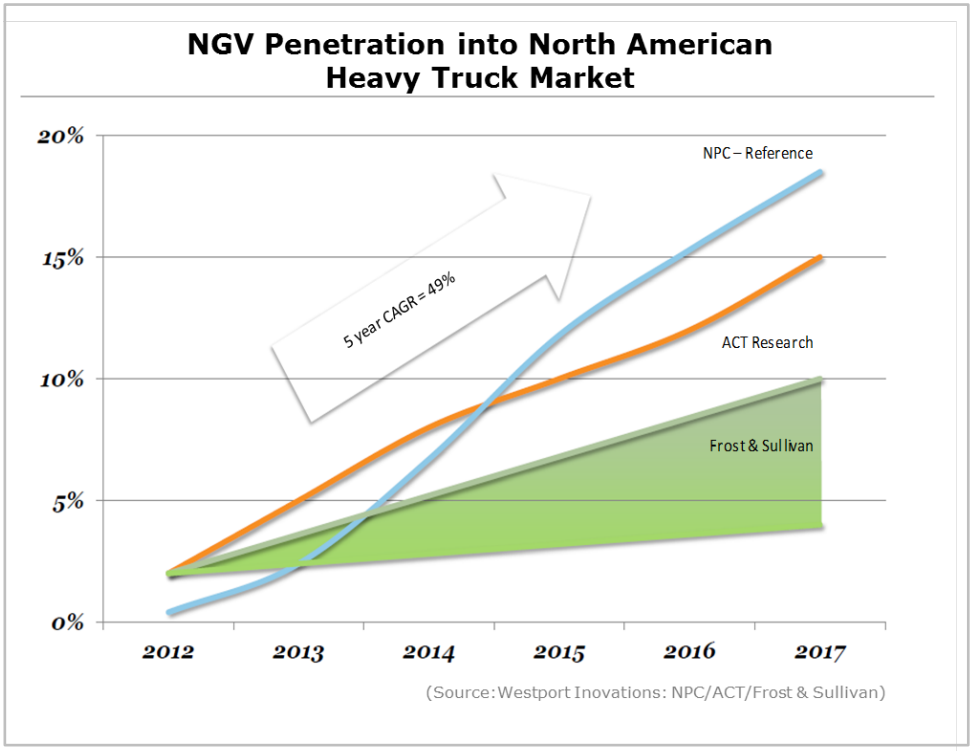
- Operator costs are dominated by fuel cost
- Other costs cannot be reduced
- Cost of diesel is not reducing
- Very limited scope to reduce fuel cost

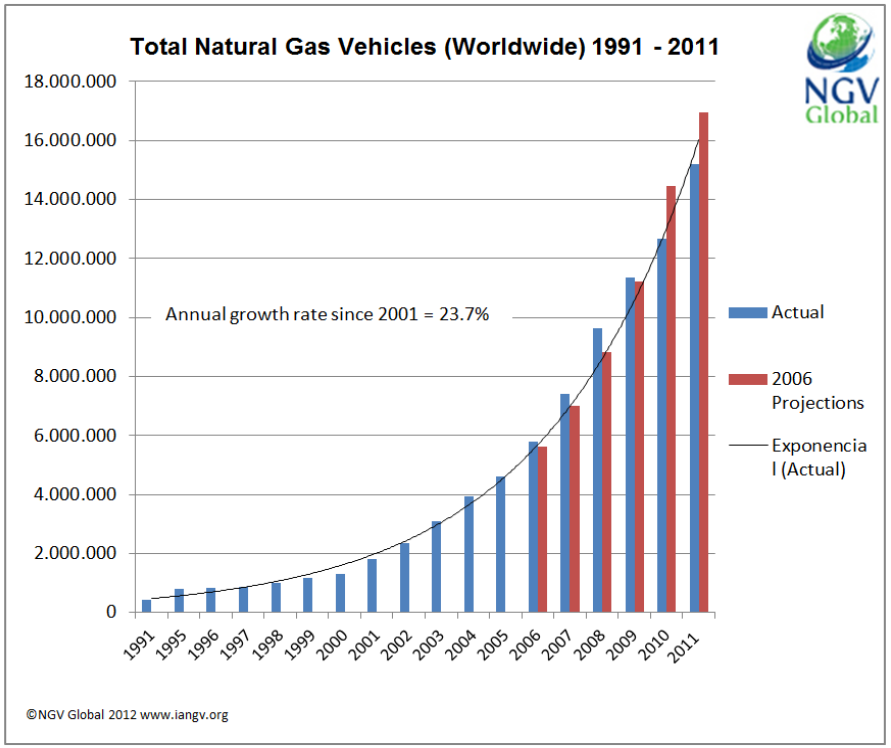
- Dual-Fuel is ideally suited to heavy-duty transport
- Other efficiency-improving / low C technologies are not effective in the HGV sector



NGV Market Developments

- The global market for NG Trucks is expected to grow at a compound annual growth rate of 14% between 2012 and 2019*
- Growth is fuelled by NG availability, cost & environmental benefits, energy security and vehicle technology availability



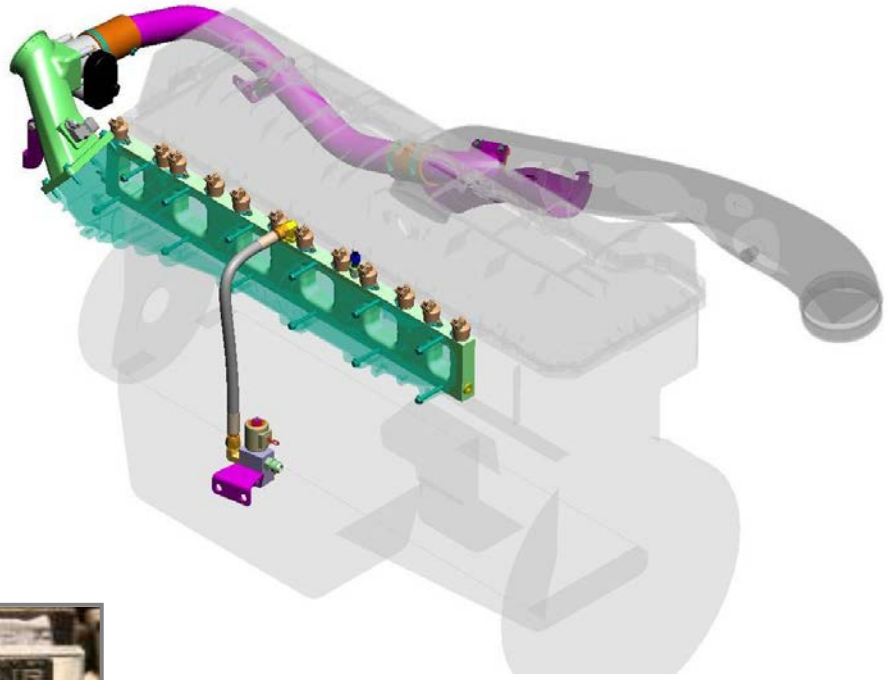


* Source: Pike Research 2012

Dual-Fuel™ Engine System

Air System

- Boost control system, VGT or CAP's boost bypass valve



Gas Injection System

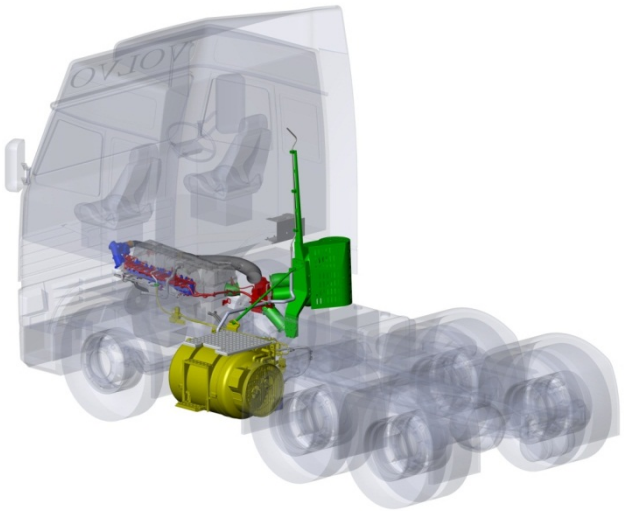
- CAP Electronic gas injectors
- Single or Multi point injection
- Compatible with LNG or CNG

Hawk™ Control System

- Woodward ECU
- Sensors
- Harnesses
- CAP interface

Developments in Dual-Fuel Technology

- VCA-Approved Euro 5 compliance on Euro 5 base-engine
- No base-engine changes
- Similar efficiency
- Lower greenhouse gas
- 100% diesel fall-back
- On-line OEM production

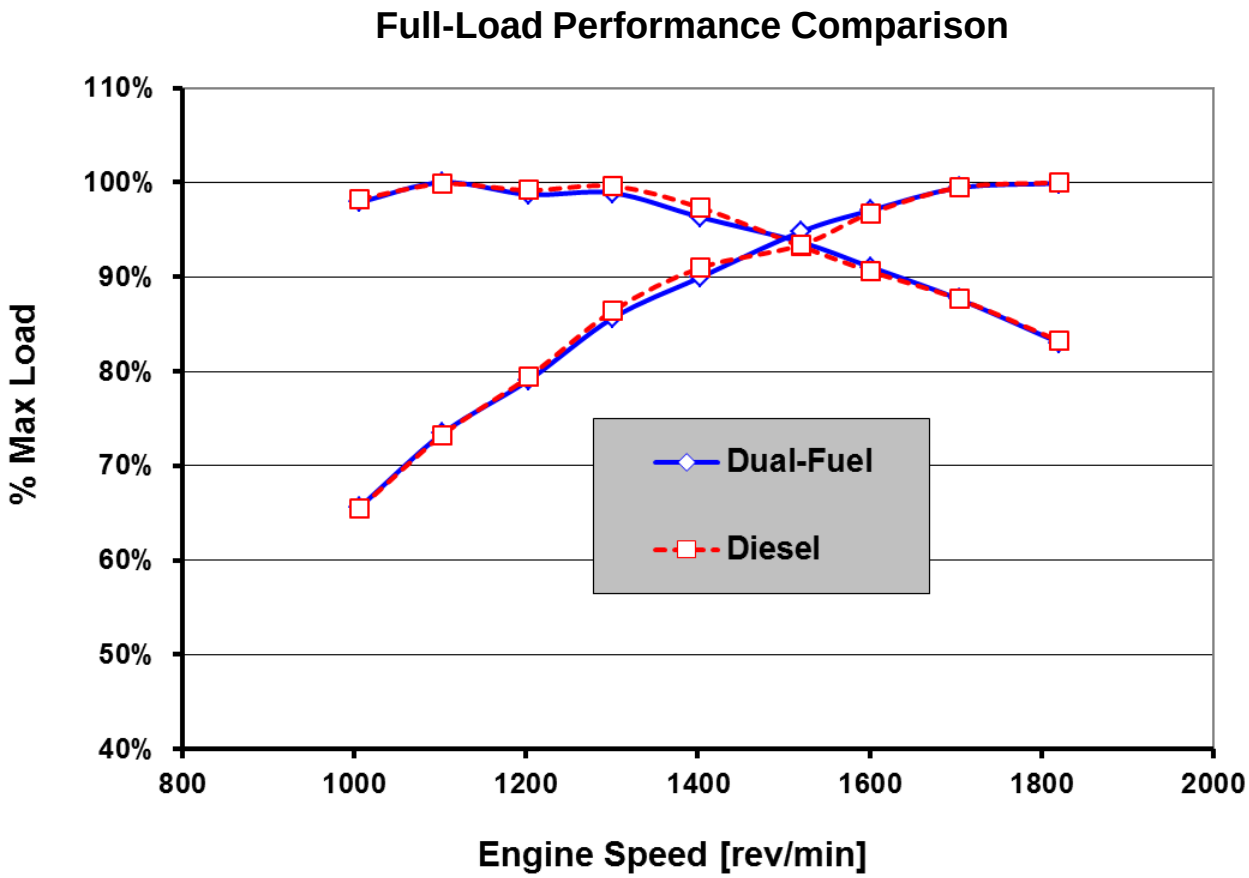


Developments in Dual-Fuel Technology

- Focus on US market since 2010
- Concept project delivered 13 litre US 2010 Dual-Fuel engine without SCR
- Complex base engine:
  - Advanced boosting system
  - Cooled, modulated EGR
  - HP common-rail FIE
  - Base engine requires SCR to meet US2010 (0.2 g/bhph NOx)
- Complex Development
  - Multi-variable development
  - DoE
  - New combustion system concepts
- Dual-Fuel engine achieved less than 50% of the baseline NOx with same engine systems and no SCR

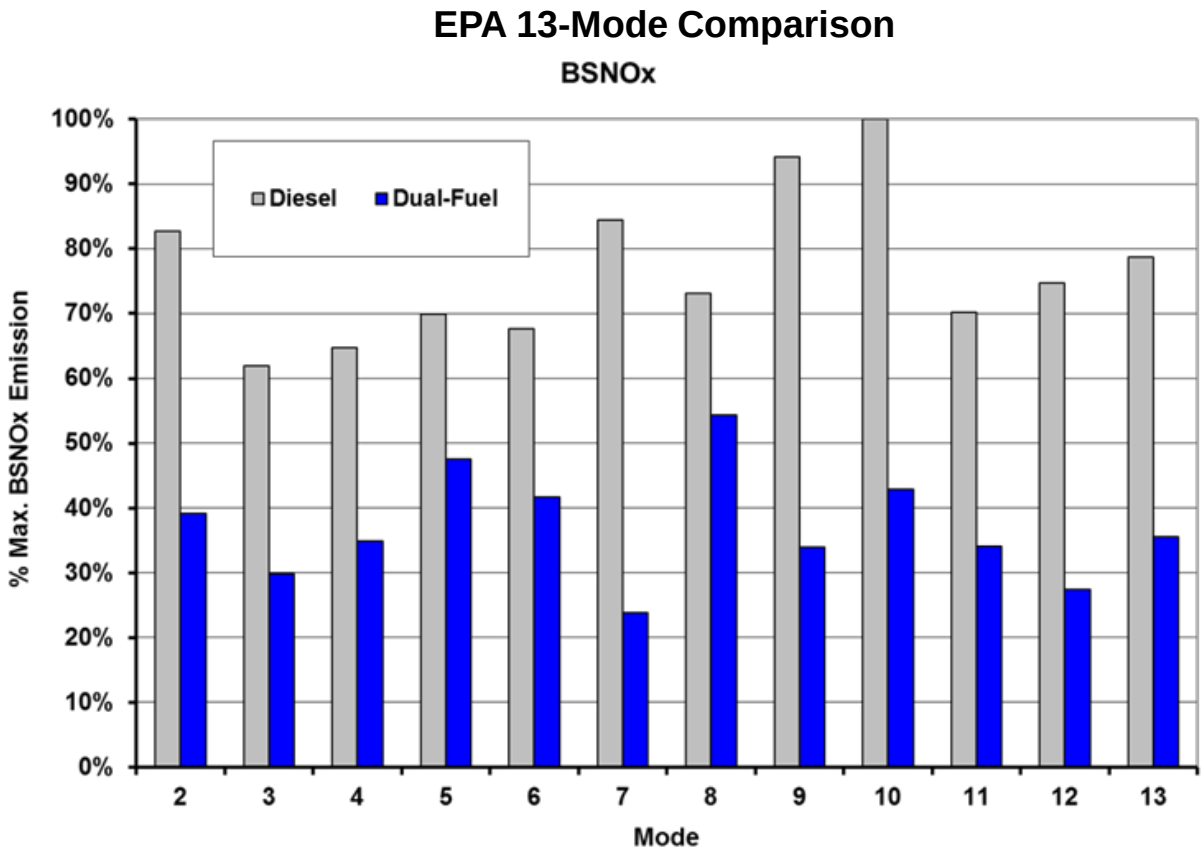
Low NOx Combustion Development

- Performance matched with 50% lower NOx
- Maximum load is limited by knock; influenced by
  - Rich limit
  - Comp. ratio
  - ACT
  - EGR / NOx
- Torque and power matched to:
  - 160 Nm/litre
  - 25 kW/litre



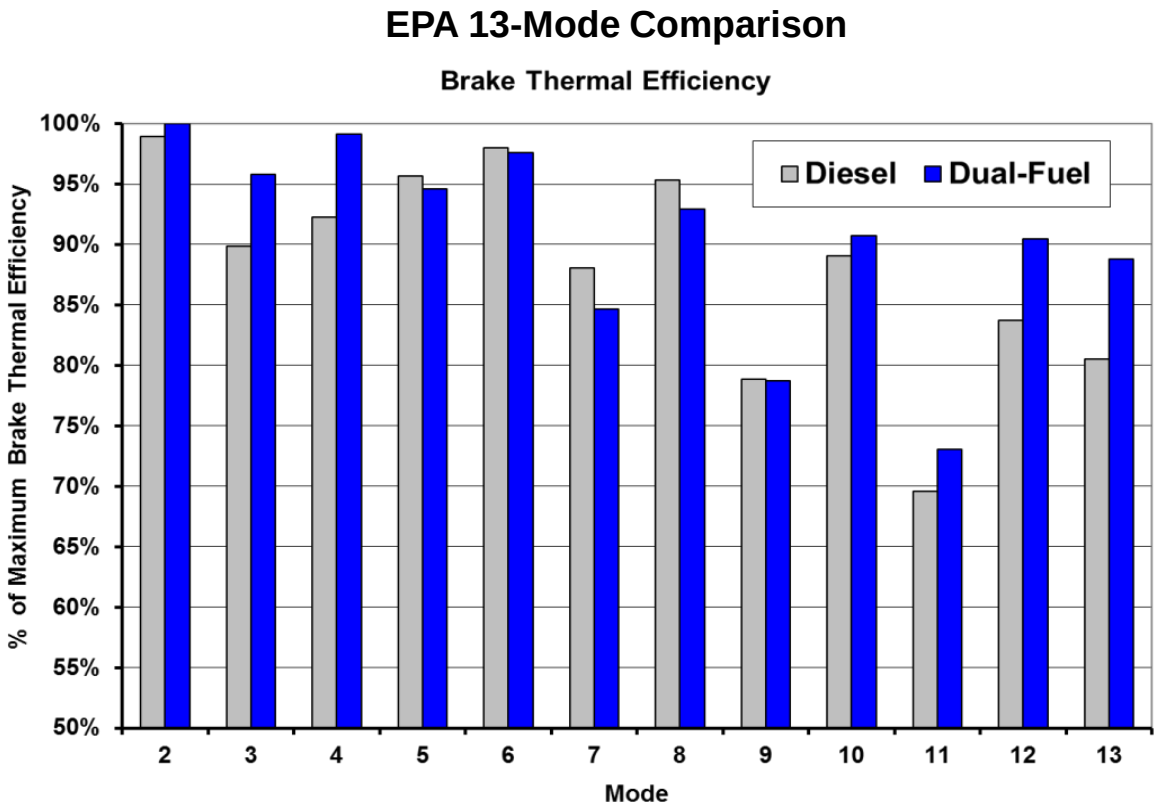
Low NOx Combustion Development

- Less than 50% baseline NOx achieved over the 13-Mode cycle
- Compliant with US2010 without SCR
- Similar levels of EGR used to base diesel engine
- Improved tolerance to EGR exhibited by Dual-Fuel system
- Improved combustion rates
- Efficiency maintained



Low NOx Combustion Development

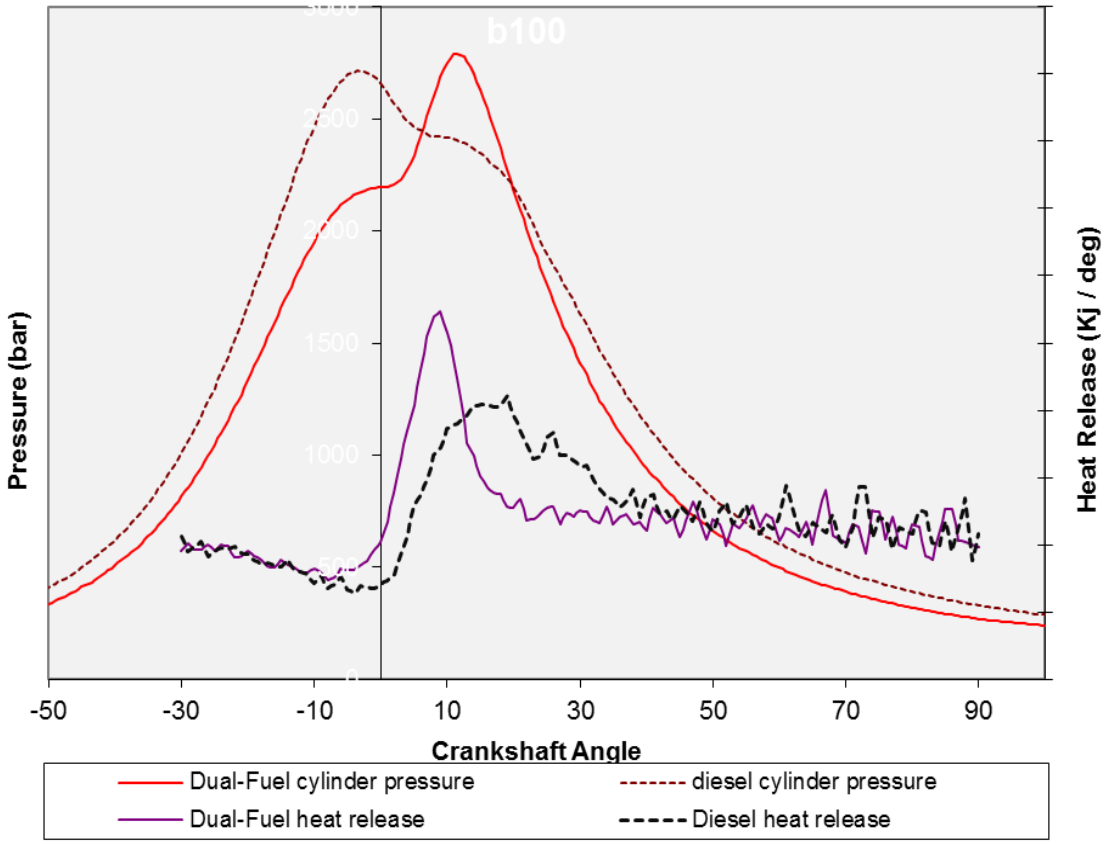
- Efficiency improved with 50% lower NOx
- Similar cycle:
  - Same comp. ratio
  - Lean operation
  - No throttled operation
- Dual-Fuel exhibits similar η_{therm} with lower NOx
- Similar exhaust temperatures
- Similar heat rejection to coolant



Low NOx Combustion Development

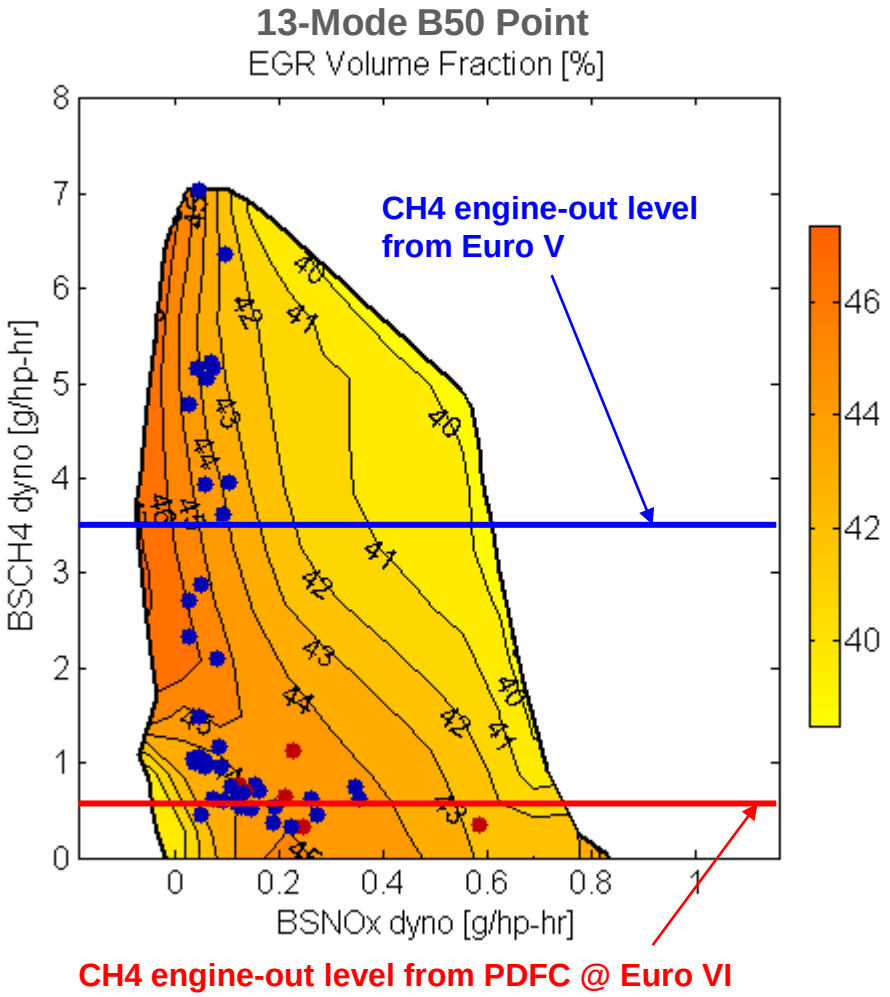
In-cylinder analysis

- Improved burn-rate observed
- Dual-Fuel exhibiting higher tolerance to EGR
- Combustion rates improved leading to more favourable NOx-Efficiency trade-off
- Limited analysis undertaken
- Now the subject for further research at Brunel University



Low NOx Combustion Development

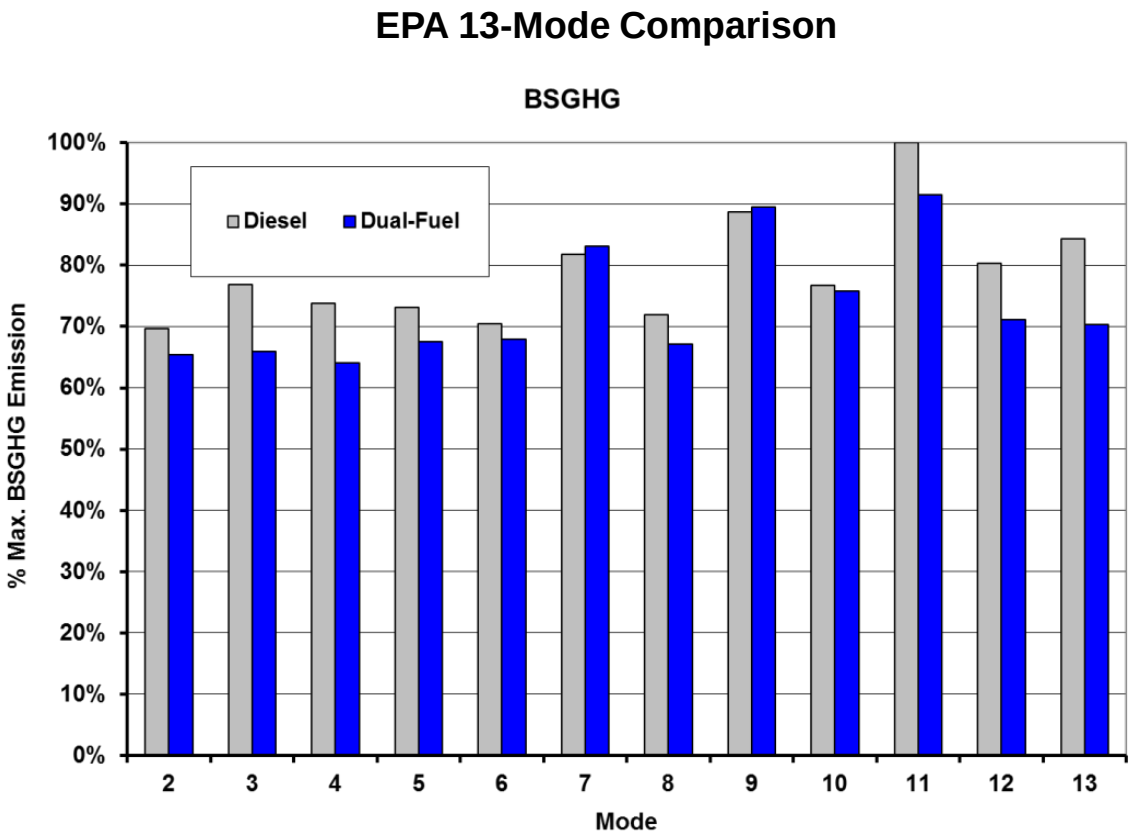
- Engine test results demonstrated significant reductions in engine-out CH_4 emission
- Pilot injection strategy included multiple pilot injections early in cycle to allow homogeneous pre-mixed combustion of diesel & gas
- Significant improvements in CH_4 engine-out emissions can be made from engines equipped with EGR & multiple pilot capability



Low NOx Combustion Development

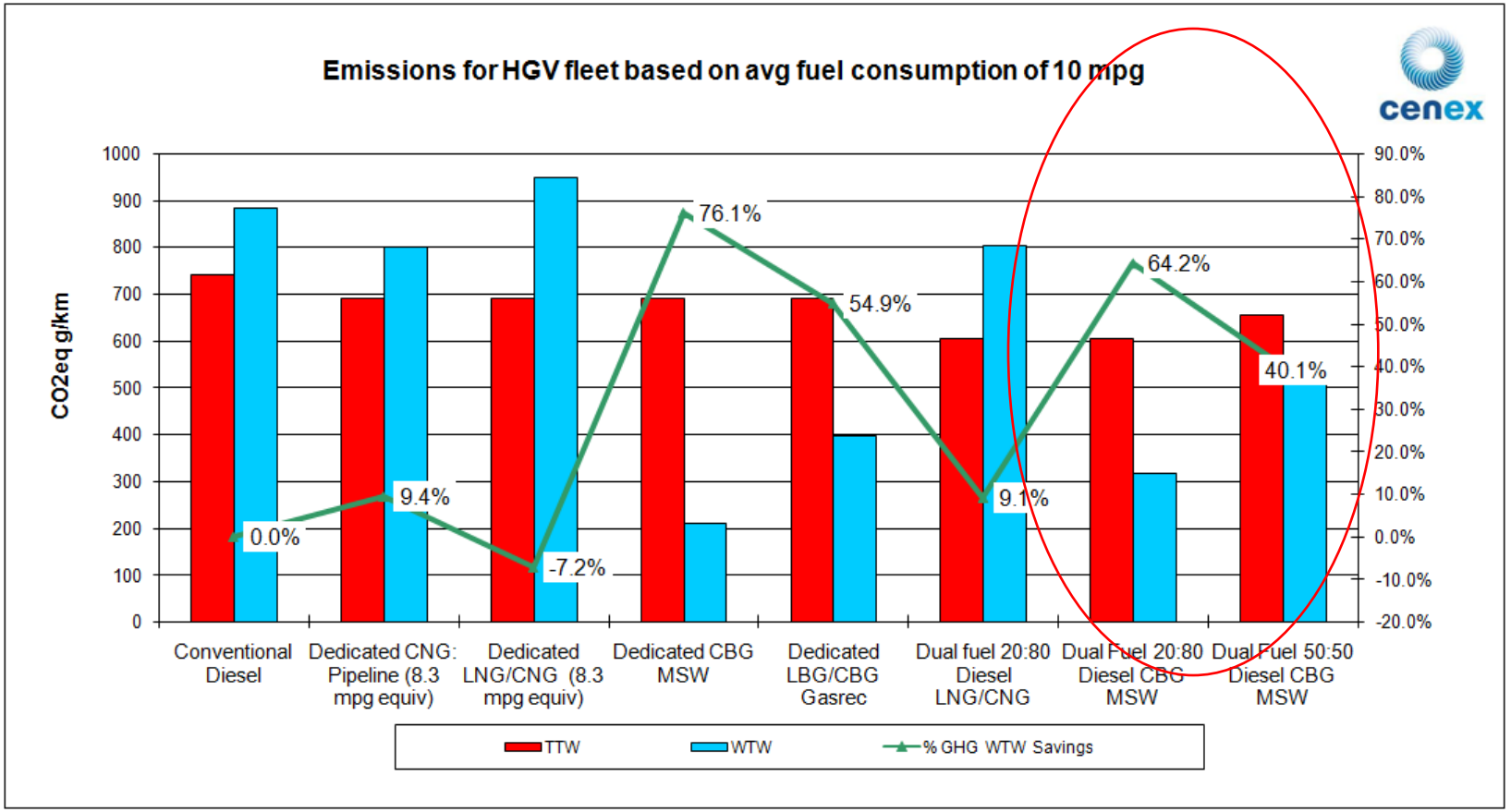
Greenhouse Gas (GHG)

- Overall THC increases due to methane emissions
- Methane emission is off-set by lower CO2 and NOx emission
- Total GHG is reduced by c.5%
- Application of oxidation catalyst will bring further improvements
- New combustion system concepts exhibit potential to dramatically reduce methane emission



Well-To-Wheels Analysis

- WTW analysis of Dual-Fuel using bio-methane shows GHG reductions of 40.1 to 64.2%



Source: CENEX UK. WTW Field trial studies conducted in 2009

Conclusions

- Natural Gas is the next major road-fuel
  - Availability (new extraction technologies & abundance)
  - Major oil & gas companies' infrastructure, supply & extraction
  - Cost (lower than diesel)
  - National energy security
  - Environmental benefits (route to bio-methane too)
- Dual-Fuel will form part of the matrix, providing a secure and reliable NG option for HGV operators who require the attributes and fall-back of a durable heavy-duty diesel engine
- Dual-Fuel has demonstrated reliability and robustness as on OEM factory-fitted option at Euro III and Euro V and has shown the potential to meet challenging US and future EU emissions regulations.