Fuels & Lubricants

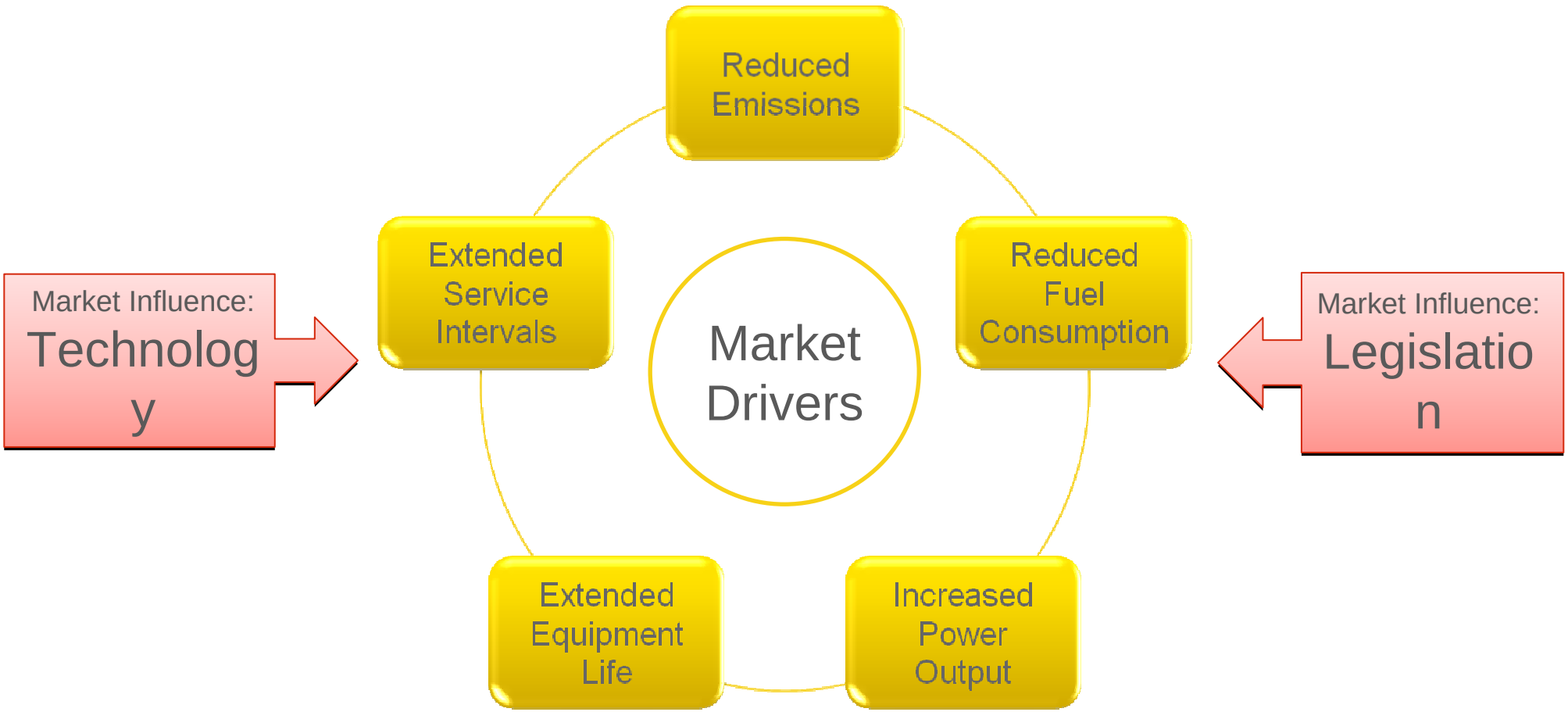
The impact for tier 4



Dr Carl Stow, Shell Lubricants Technology, Shell Technology Centre Thornton

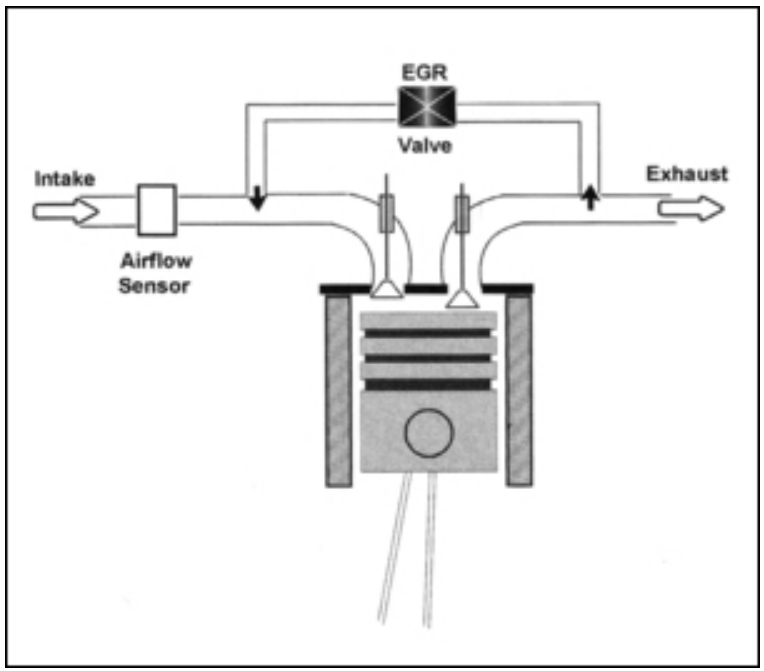
Market Drivers

What Drives the off-highway HDDEO Market?

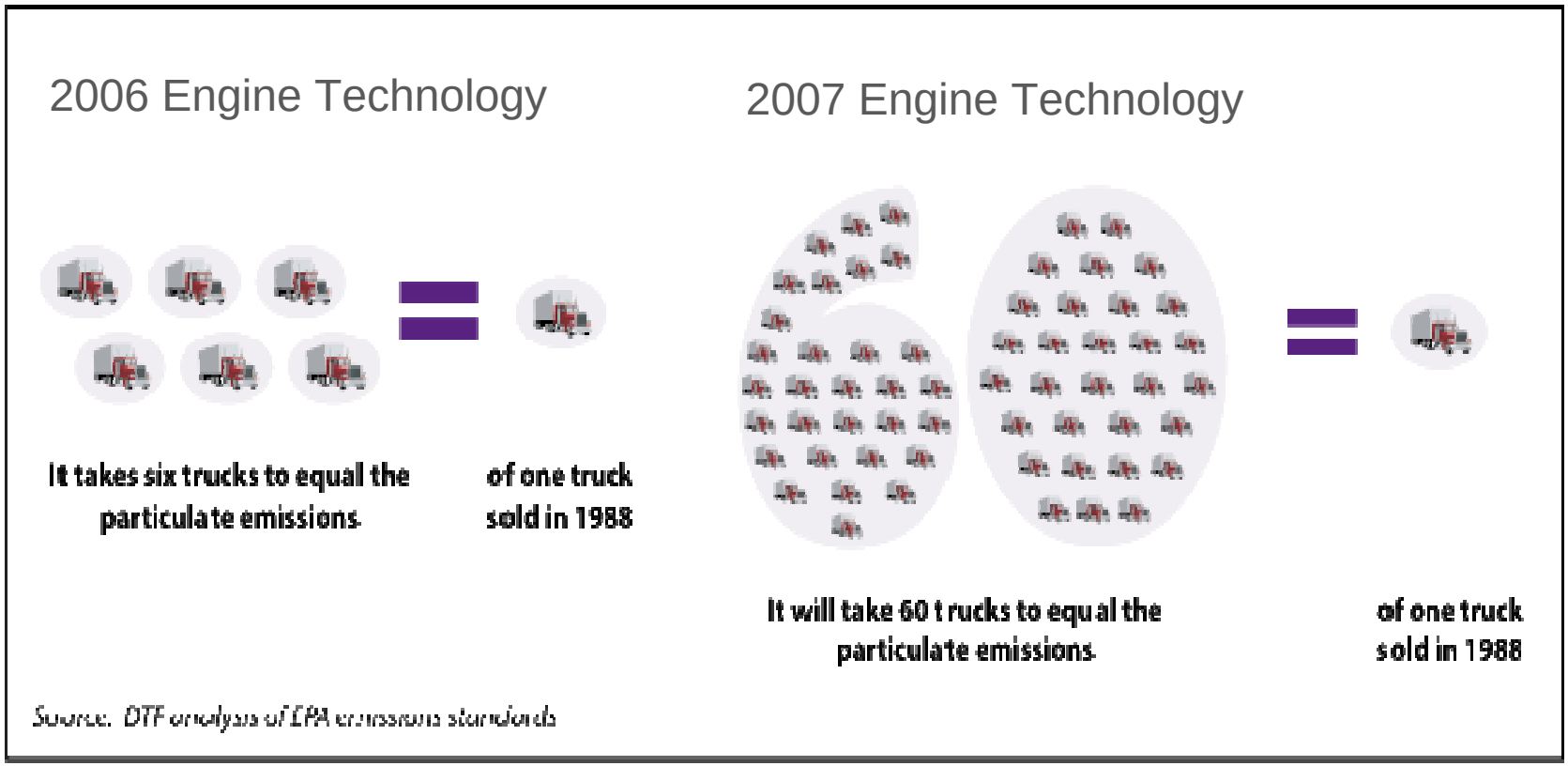


Market Influence: Technology

- Increased energy efficiency and power output
  - Improved fuel injection systems
  - turbocharging, VGT
- Aftertreatment Devices
  - NO_x control (EGR)
  - urea metering
  - DPF soot regeneration
  - oil quality monitoring
- Hybridisation - eg Cat, Komatsu, Liebherr
  - Integration of electric motors within driveline
- Factors affecting hardware
  - Reduction in fuel Sulphur
  - Clean fuels
  - Renewable fuels

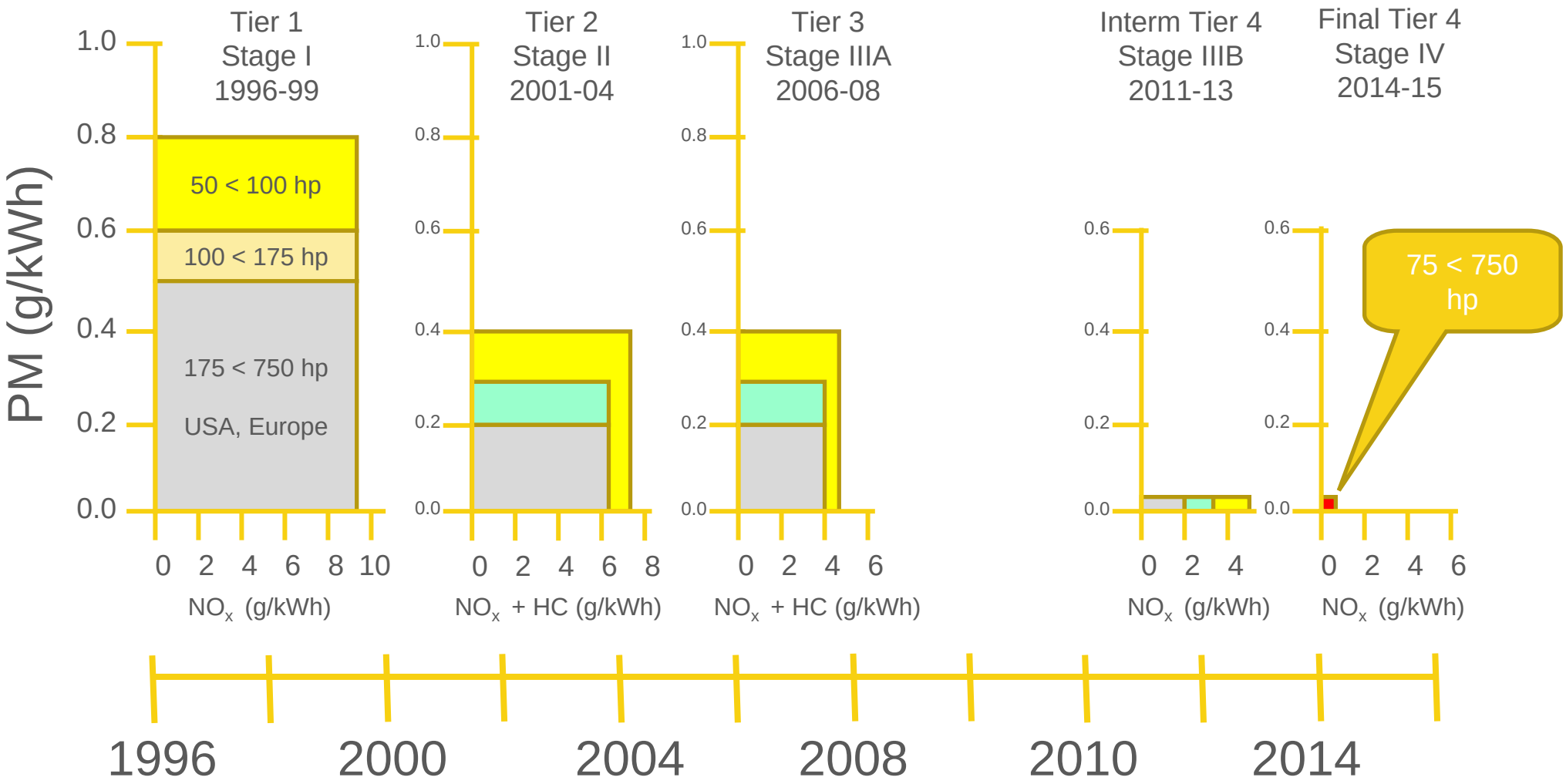


Market Influence: Legislation



1 Off-highway vehicle built in 1996 = 60 Off-highway vehicles built in 2014

Non-road Diesel Engine Emission by Power Category



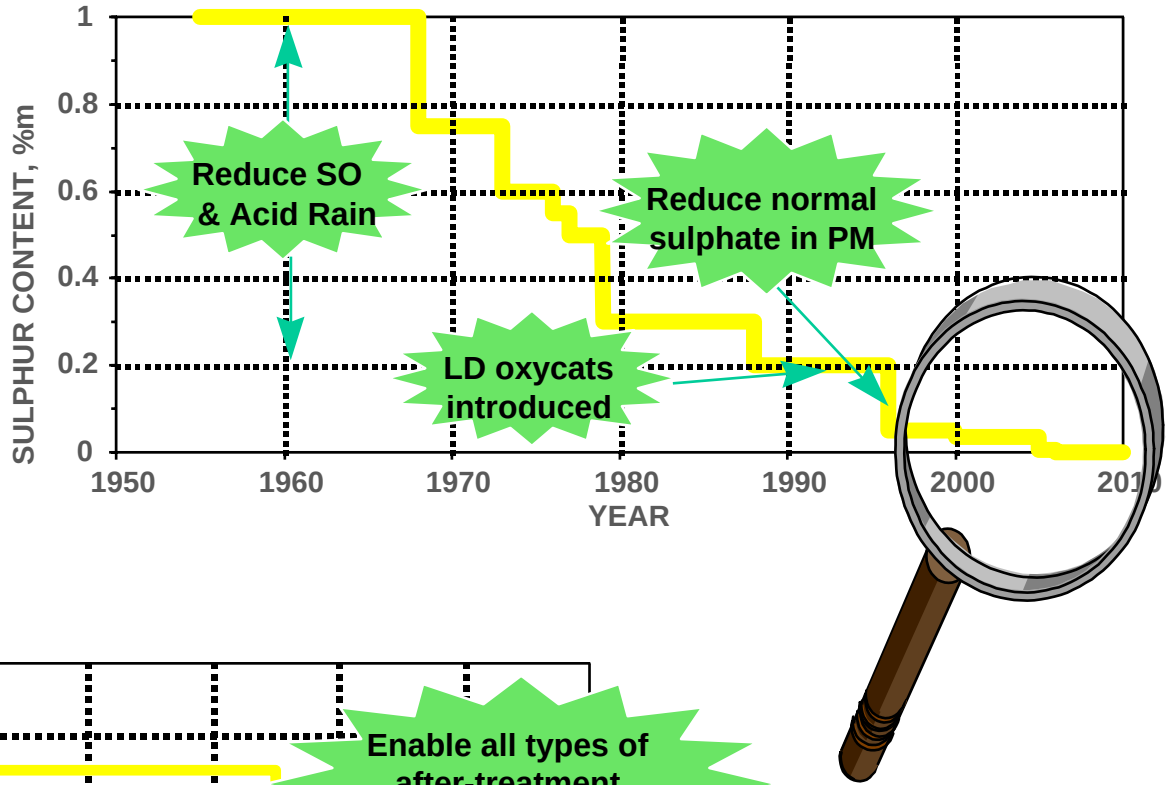
Fuel specifications

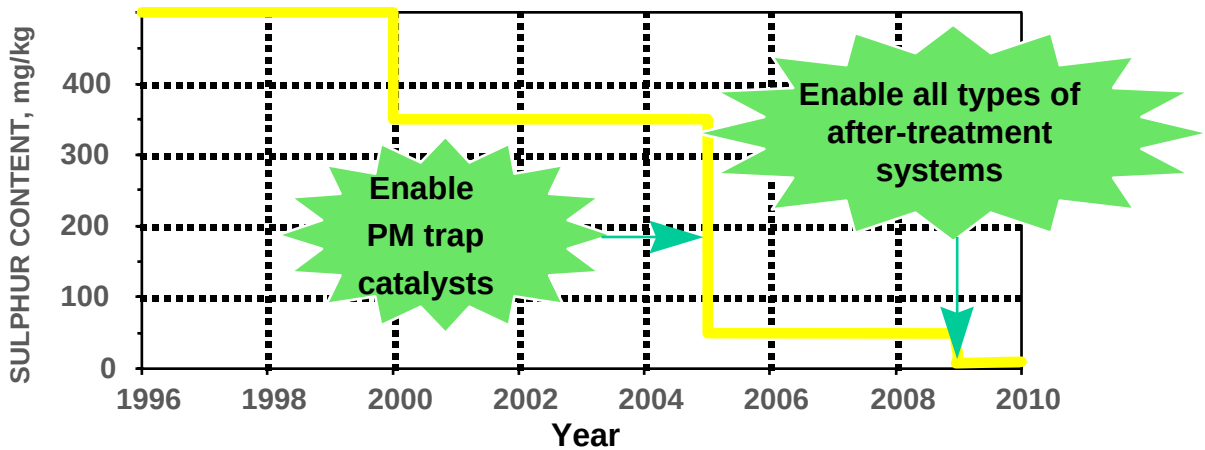
Reducing sulphur and increasing biodiesel content in gasoil

Reduction in fuel sulphur

European Road Diesel (EN 590)

- 80% Reduction 1955 to 1988
  - 1.0%m to 0.2%m
- Further 90% Reduction 1999 to 2005
  - 2000mg/kg to 50mg/kg
- Further 80% reduction 2005 to 2007
  - 50mg/kg to 10mg/kg





Fuel Quality - Europe

- 2009/30/EC requires the sulphur content of gasoil used for non-road mobile machinery (Class A2) to comply with a “sulphur-free” description by 01/01/11
- FAME (biodiesel, fatty acid methyl ester) increased to 7%vol
  - pure FAME Quality controlled by EN14214
- Many European Member States specify the on-road fuel quality EN590 for use in off-road vehicles (with marker/dye for tax)
- Market experience with this product appears to be generally good:
  - Zero sulphur
  - FAME at 5%vol
- Later introduction for Rail (2012)

“Sulphur-Free”:

Europe <10 mg/kg

Japan <10 mg/kg

US < 15 mg/kg

Fuel Quality - UK

- In the UK, gasoil is specified within BS 2869:2010
- The principal changes in the new specification are:
  - the sulphur content of Class A2 fuel is reduced to conform to a sulphur-free description
  - the introduction of an oxidation stability value for the middle distillate fuels, with associated test methods for high and low biofuel (FAME) blends
  - the introduction of a lubricity requirement for A2 middle distillate fuel
  - the inclusion of up to 7.0% (fraction by volume [V/V]) of Fatty Acid Methyl Ester (FAME) to the appropriate British Standard is permitted in both grades of middle distillate fuel
  - maximum viscosity values have been set for the middle distillate grades
  - guidance is given to address material compatibility and operability issues associated with the use of FAME to the maximum concentrations specified
  - the addition of cetane number or derived cetane number

Comparison with EN590 (Road Diesel)

Property	BS 2869 Class A2	BS 2869 Class D	EN 590 UK
Cetane Number	>45	>45	>51
Density (kg/m^3)	820-	820-	820-845
Viscosity (cSt)	2.0-5.0	1.5-5.0	2.0-4.5
Sulphur (mg/kg)	<10 (20)	<1000	<10
FAME (%v)	<7	<7	<7
Polyaromatics (%m)	-	-	<8
Oxidation (g/m^3)	<25	<25	<25
Flash Point (°C)	>56	>56	>55
CFPP (°C) s/w	-4/-12	-4/-12	-5/-15
Lubricity (μ)	<460	<460	<460
Water (mg/kg)	<200	<200	<200
Carbon residue	<0.3	<0.3	<0.3
Particulate (mg/kg)	<24	<24	<24
Ash (%m)	<0.01	<0.01	<0.01
Distillation @250 (%v)	<65	<65	<65
Distillation @350 (%v)	>85	>85	>85
Distillation T95 (°C)	-	-	<360

Differences between Class A2 and EN 590 product:

- Cetane Number

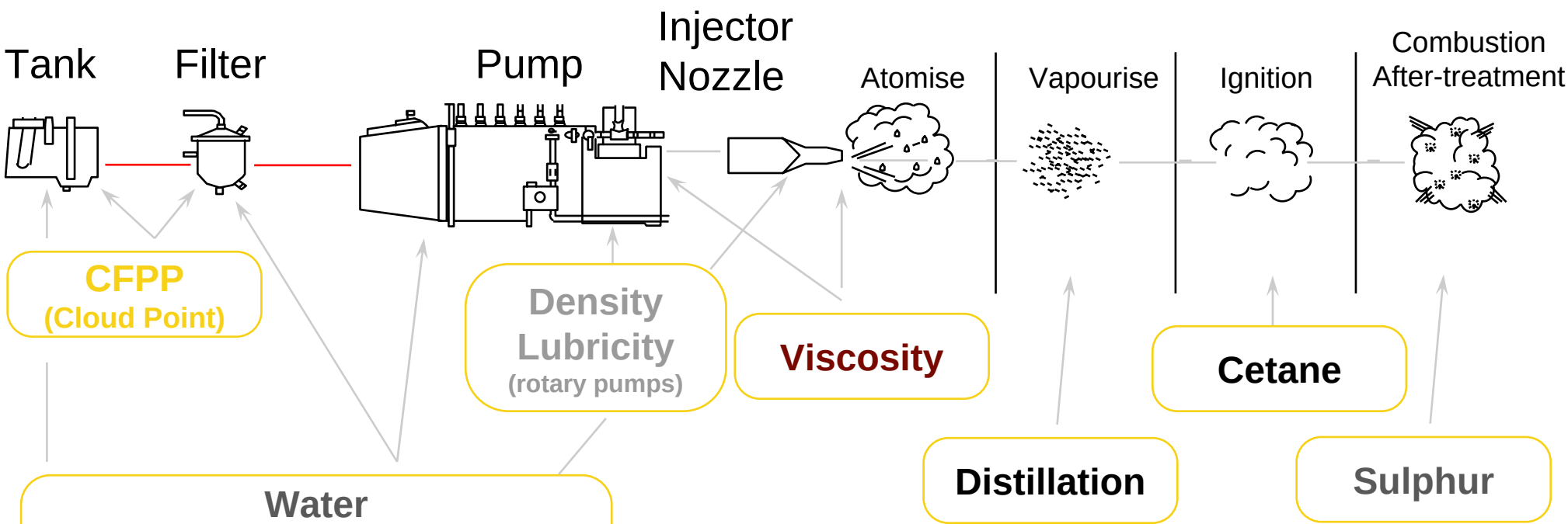
- Cold Flow (CFPP)

Not specified:

- Polyaromatics

- T95

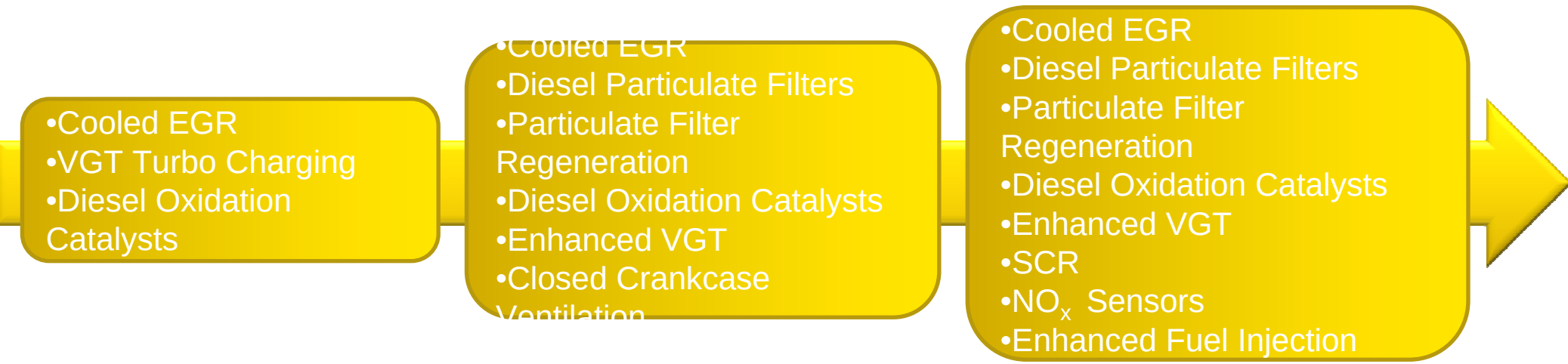
Impact of Fuel Properties



Engine and exhaust aftertreatment technology response

Applicable Technologies by Tier

- Technology currently used for on-road emissions controls will be used to control emission in non-road equipment in the future



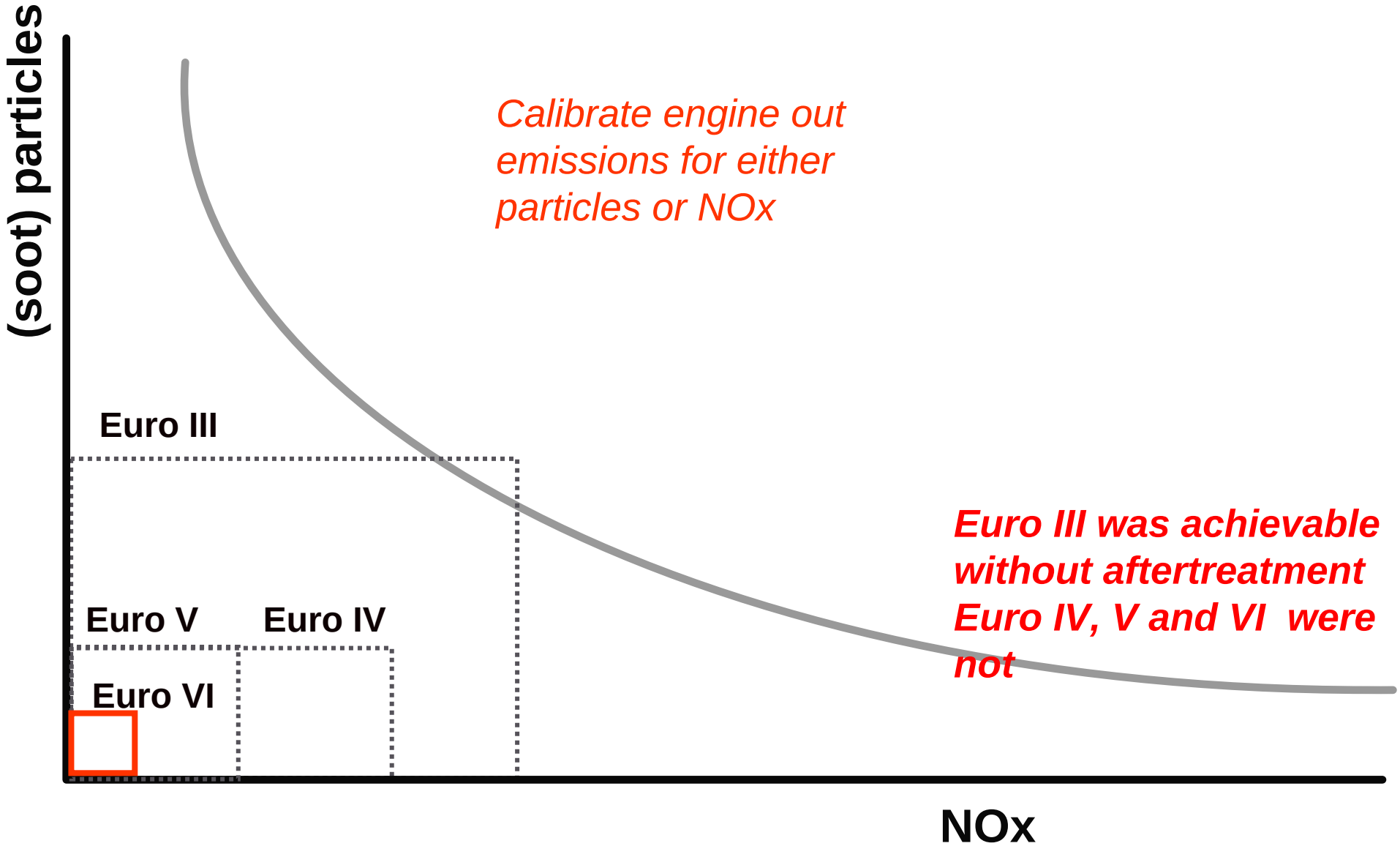
Tier 3
2006-08

Tier 4
2011-15

Future

- EGR= Exhaust Gas Recirculation, VGT=Variable Geometry Turbo charging, SCR=Selective Catalytic Reduction

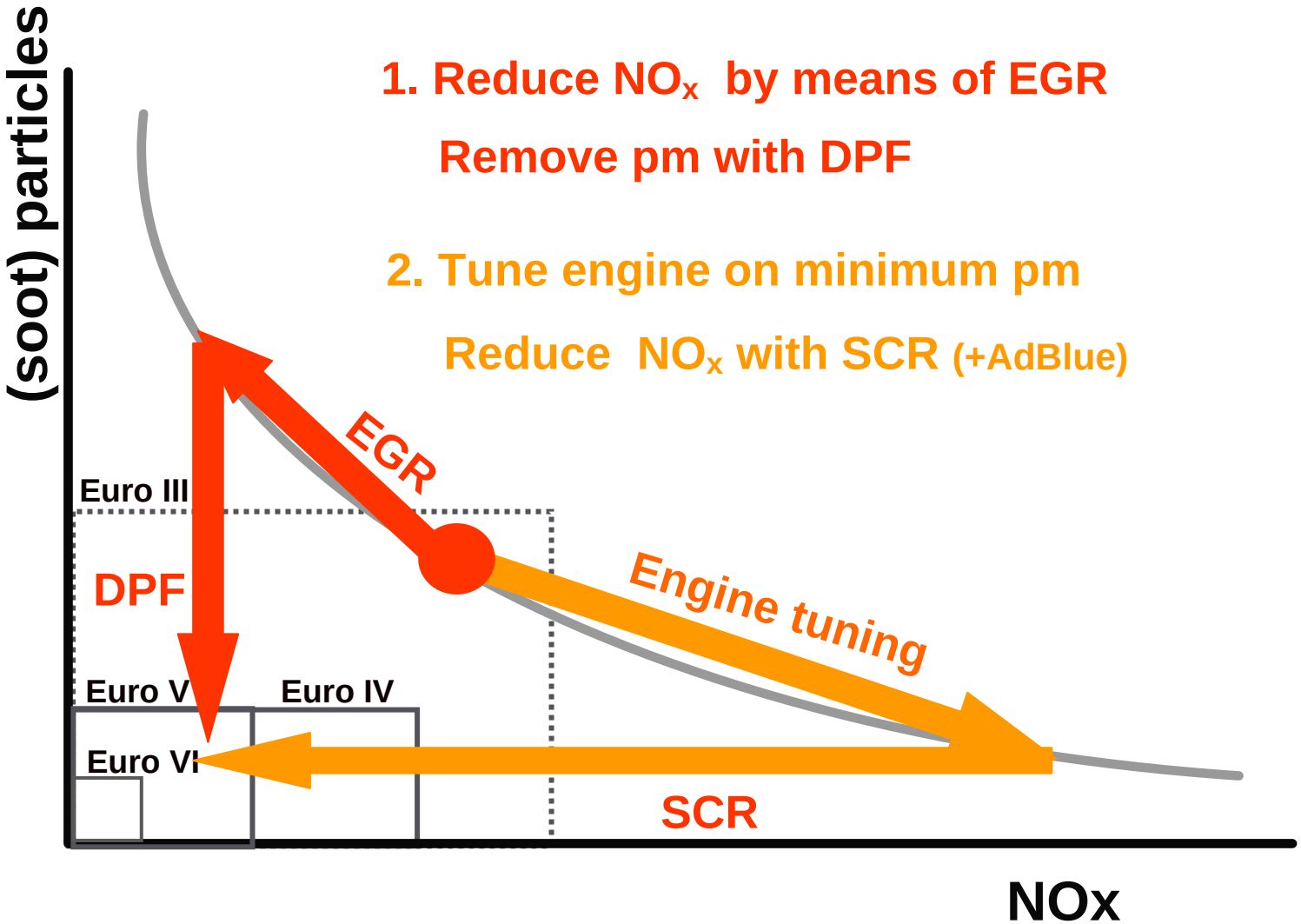
The on-highway emissions story



Calibrate engine out emissions for either particles or NOx

Euro III was achievable without aftertreatment Euro IV, V and VI were not

Two basic approaches for Euro IV and V



Tier 4i / Stage IIIB have the same choices

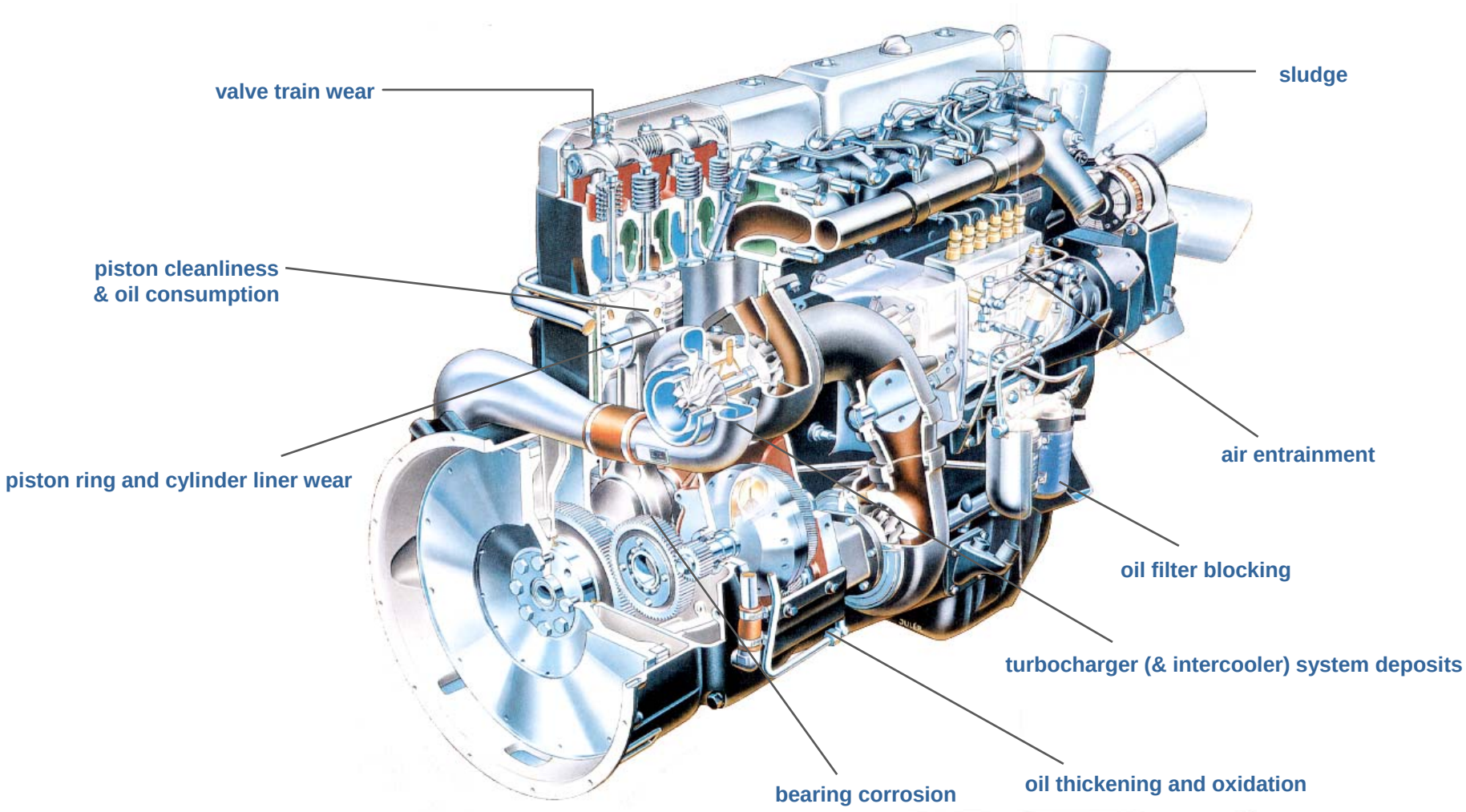
Lubricant chemistry can affect after-treatment systems

Sulphur:	- de-activates oxidation catalyst - poisons SCR catalyst - forms sulphate particles blocking the DPF
Ash:	- blocks DPF (particles cannot be regenerated)
Phosphorus:	- poisons catalysts (oxicat & SCR) - poisons NO_x sensors

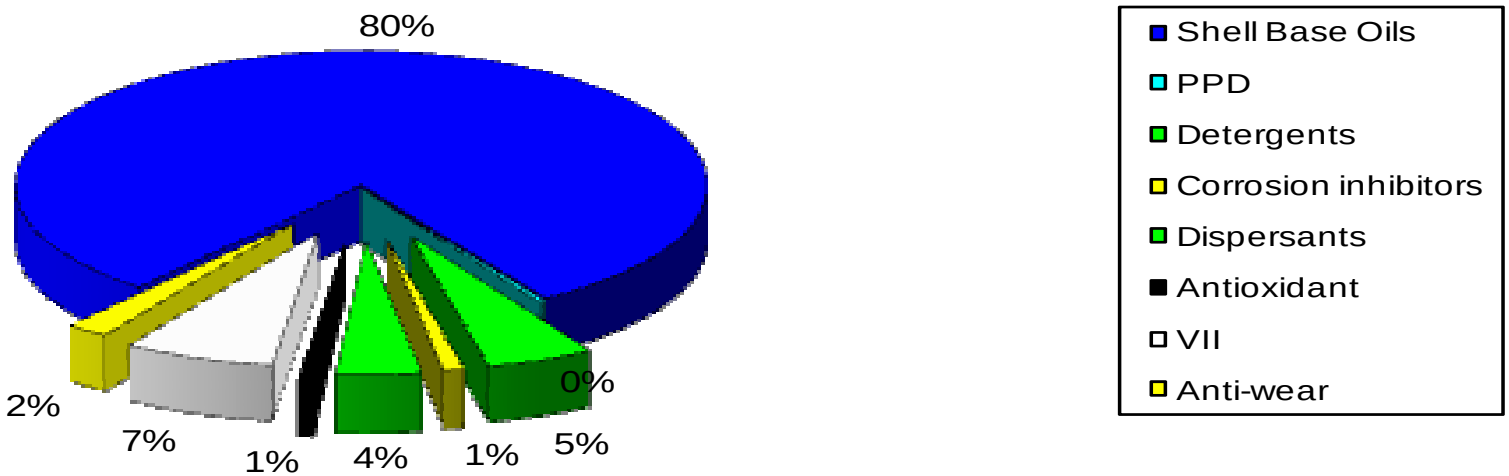
Engine oil technology response



Lubrication requirements in current diesel engines



Typical Composition of a HDDEO Lubricant



HDDEO Lubricants contain up to 20-25% performance additives

New Technology Engines necessitate New Technology Lubricants

Requirements of modern lubricants

■ Dispersant capability	to keep the finer particles suspended in the oil to prevent deposits
■ Cleaning capability	Detergents have to keep the engine parts clean (eg the piston)
■ Wear protection	Additives that can withstand high loads for longer times
■ Temperature stability	to maintain performance under high thermal stress
■ Acid absorption	to protect the engine from corrosion
■ Viscosity stability	to prevent the lubricant from excessive thickening

HDDEO oil specification evolution

- Exhaust emissions legislation drives engine and exhaust aftertreatment design changes which drive engine oil specifications

NORTH AMERICA

Emission Regulations	1994	1998	2004	2007	2010
Specifications	API CG-4	API CH-4	API CI-4	API CJ-4	API CJ-4

EUROPE

Emission Regulations	Eu II (1996)	Eu III (2000)	Eu IV (2005)	Eu V (2008)	Eu VI (2013)
Specifications	ACEA 96 & 98	ACEA 1999 (E5-99)	ACEA 2004 (E6-04, E7-04)	ACEA 2008 (E6-08, E9-08)	ACEA 2012

Compositional constraints introduced in oil specifications for after-treatment device protection

	Oil Composition		
	%Ash	%Sulphur	%Phosphorus
Current Oils			
Typical ACEA E4 top-tier oil	1.9	0.4	0.12
Typical API CI-4+ oil	1.4-1.5	0.4	0.12
Specification Limits			
ACEA E6, MB 228.51	1.0 max	0.3 max	0.08 max
ACEA E9, API CJ-4	1.0 max	0.4 max	0.12 max
JASO DH-2	0.90-1.10	0.5 max	0.12 max

- OEM concerns re effects of ash (DPF blocking), phosphorus and sulphur (poisoning) on after-treatment device durability
- These lubricant specifications restrict performance additives significantly
- require “low SAPS” oils (Sulphated Ash, Phosphorus, and Sulphur)

Future HDDEO Specifications

- No further changes, ie reductions, to chemical limits for sulphated ash, phosphorus and sulphur anticipated US/Eu/Japan engine oil specifications.

- US
  - API CJ-4 oils formally adopted for US 2010 emission compliant engines.
  - PC-11 in US. Likely to be around 2015 timeframe. Discussions are just beginning. Will be predominantly driven by replacement of many of the engine tests

- Europe
  - ACEA 2012 specs to be similar to ACEA E9, E6, E4. Bio fuel compatibility engine test (for durability) under development. Lab based test for low temperature viscosity test to address bio fuel related oil oxidation concerns under consideration. Potential focus on fuel economy.

- Japan
  - JASO DH-2 specification tests currently under revision; to be replaced by US ASTM tests, eg, Nissan TD25 replaced by Caterpillar test, and Mitsubishi 4D34T by Cummins valve train wear test. JASO DH-2 oil quality unchanged in next 5 years.

Energy Efficiency - Fuel Economy, CO2 reduction

- HD engine/ truck legislation in US (2014), Japan (2016) proposed. EU timeframe not known. Fuel consumption reduction in engine / truck designs generally expected to improve by 15% from 2005 to 2020. Contribution from engine lubricants expected to be significant.

- Significant OEM interest in fuel economy from lubricants– Daimler and Volvo adopting WHTC/WHSC test cycles for fuel economy testing. Japanese OEMs, e.g. Isuzu and Hino, have or are developing specific engine oil fuel economy tests. There are no current plans for an Industry specification HDDEO fuel economy test (focus of such a test is unclear as to whether improvement relative to reference oil as fresh oil or retention of FE benefit most appropriate).

- OEMs active looking at xW-30 grades, and investigating reduced HTHS viscosity relative to current. 3.5 mPa-s minimum preferred by EU/US OEMs. Japanese OEMs already looking at 0W-20 oils, & Iveco published 0W-20 study. Major concern from all OEMs is engine durability at viscosity grades at or less than 5W-30 and reduced HTHS. On highway OEM increased interest currently not shared by customers.

- FE in Off-highway equipment: high level of OEM/ customer interest.

Shells response to future fuel economy challenges

Shell Lubricants – 4D Approach

Experts in the field provide unmatched insight into problems & opportunities



Fundamental science applied for complete understanding of lubricant design needs

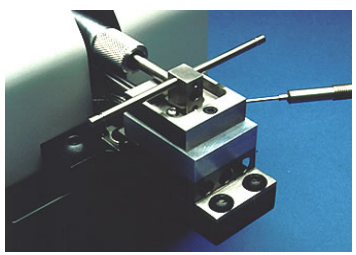
Innovative & bespoke component selection to meet design objectives

Rigorous testing using unrivalled methods & facilities

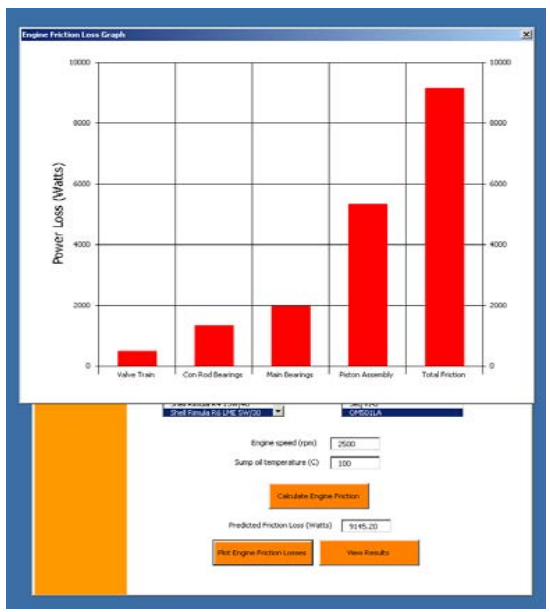
Define: Our objective is to generate and demonstrate fuel economy benefits for HD applications

Shell Lubricants – 4D Approach - Design

- In-depth understanding of the **Design requirements** of a fuel economy lubricant
- Generation the fundamental theoretical and practical knowledge
- This enables Shell to understand where in the mechanical system the fuel economy benefit comes from
- Generated through:
  - —Laboratory scale testing
  - —theoretical vehicle & system modelling

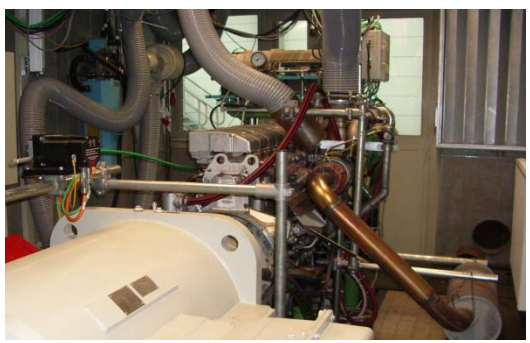


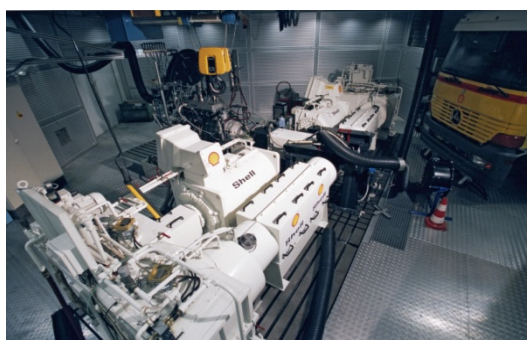




Shell Lubricants – 4D Approach - Develop

- **Develop** fuel economy lubricants and supporting data
- **Develop** new lubricants with the technical edges discovered during the design stage
- Generation of engine and system test data
- Engine testing – key global engines and test cycles
- Driveline testing – engines to be testing in combination with transmissions to aid the understanding of the full driveline lubricants proposition
- Developing new testing methods





Shell Lubricants – 4D Approach - Demonstrate

- **Demonstration** of the benefits of fuel economy products

- Through market and sector specific field trials
- **On-Highway – trucking, buses and delivery**
- **Off-Highway – agriculture, construction and mining**
- **Generating customer focused marketable claims**













