BOLK: Impact of biofuels on engine technology and emissions

TNO | Knowledge for business

CE Delft

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Contents

- Objectives / introduction
- Engine development & compatibility with renewable fuels
- Emissions with renewable and other alternative fuels
- Conclusions & Recommendations

Objectives

- Impact biofuels and other alternative fuels on emissions of current technology vehicles

- Impact biofuels on emissions of future vehicles (up to 2020)

Fuels considered

SI engines			diesel engines	
low % blends in petrol	high % blends neat fuels	gaseous fuels	diesel low % blends	high % blends neat fuels
E5 - E10 ethanol	E85	LPG	B5-B10 (FAME)	B20-B100
	E100	CNG	VPO (PPO)	E95 + ignition improver
ETBE		CBG (biogas)	XTL: BTL, GTL	100% XTL
Butanol / biopetrol			HVO	100% HVO
				methanol / DME

Fuels development

Governments steer the quantity of bio components in fuels for road transportation

	in the total amount of fuels sold for road transport	in petrol min.	in diesel min.
2007	2%	2%	2%
2008	3,25%	2,5%	2,5%
2009	4,5%	3%	3%
2010	5,75%	3,5%	3,5%
2020	10% ?		

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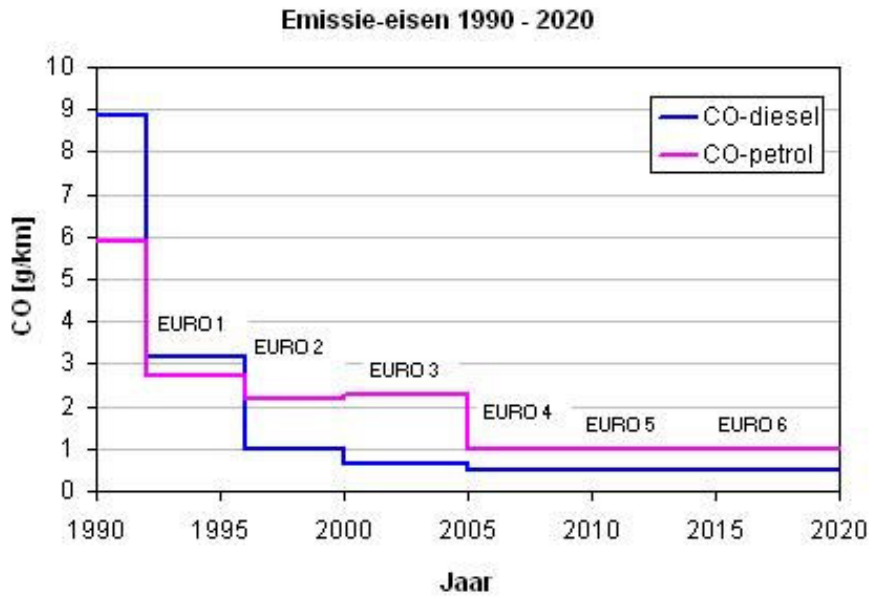
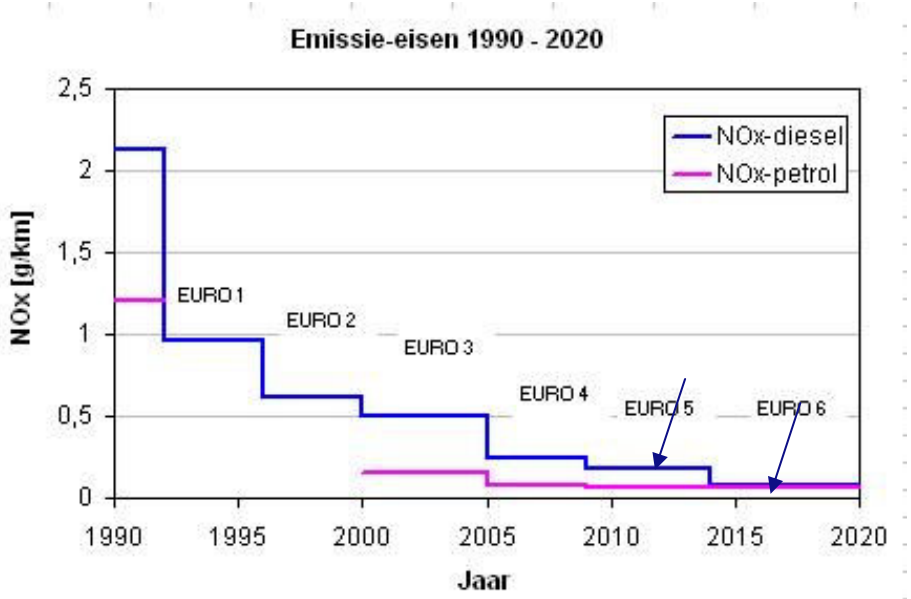
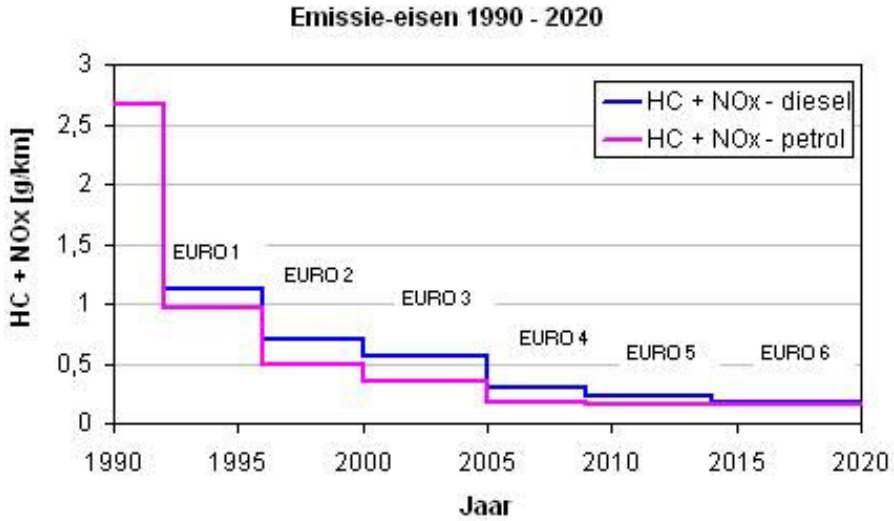
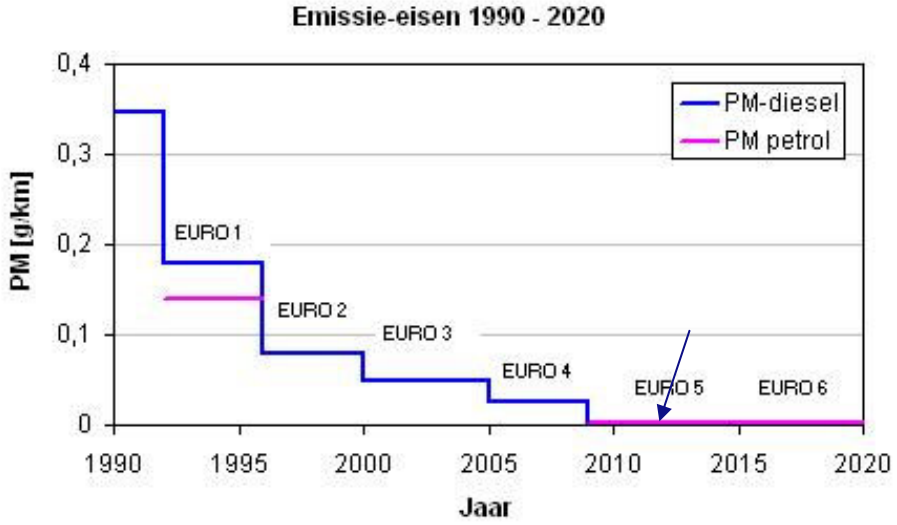
Emissions legislation passenger cars









Engine development towards 2020

Engine	Spark ignition	Compression ignition
Emphasis	CO2 emission reduction	NOx & PM emission reduction
Developments	Downsizing (turbocharging, DI, VVA, etc.) Further optimisation 3-way catalyst	Advanced emission control systems: -Diesel particulate filter -Improved EGR systems -NOx reduction catalysts

- (almost) equal emission performance for otto and diesel with Euro VI / 6 !

Engine compatibility with renewable fuels

Aspect biofuel	Consequence
Biofuels not implemented in emission legislation (phasing in in future legislation)	Emissions may vary and exceed limits
Energy density is often lower	Reduced driving range and/or increased tank size
Biofuels can contain impurities	Possible catalyst deterioration and engine fouling
Biofuels are more aggressive	Metal corrosion Deterioration Elastomers + coatings
Different boiling range, viscosity & stability	Engine oil deterioration

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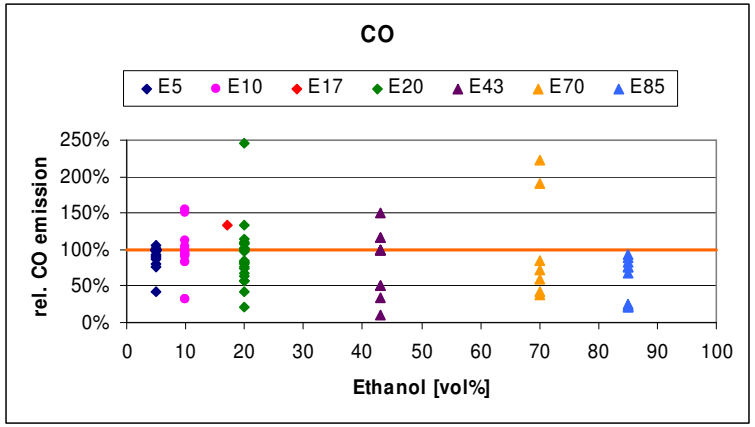
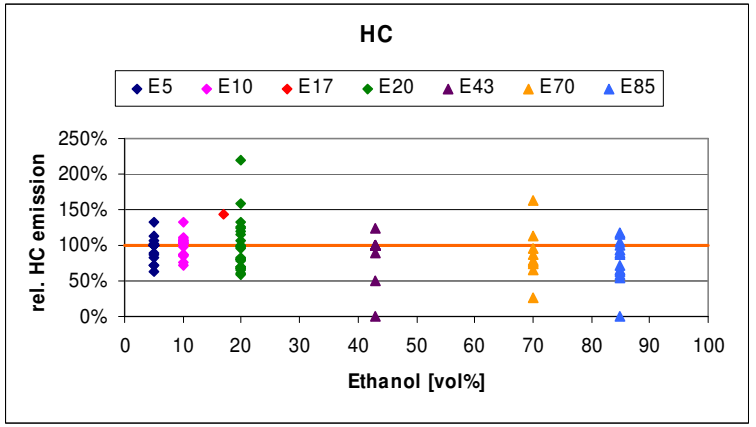
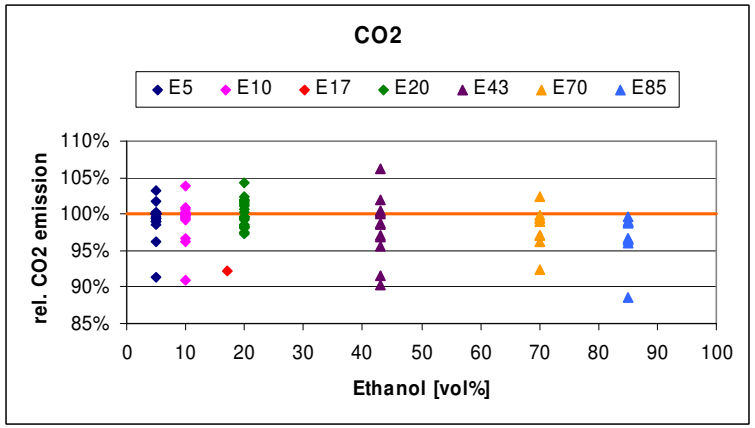
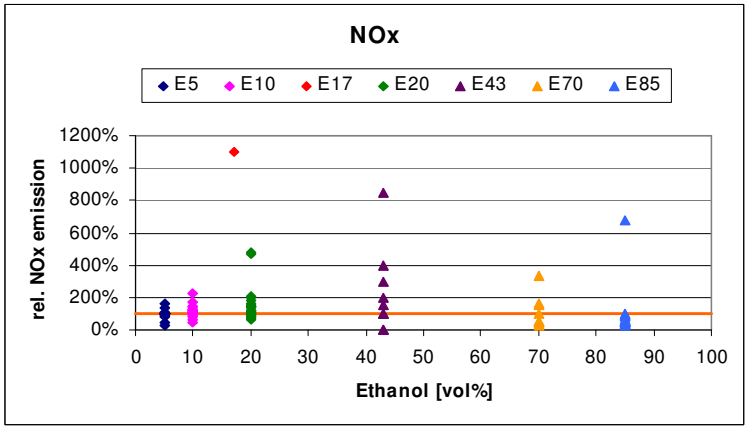
Effects ethanol (petrol = 100%)

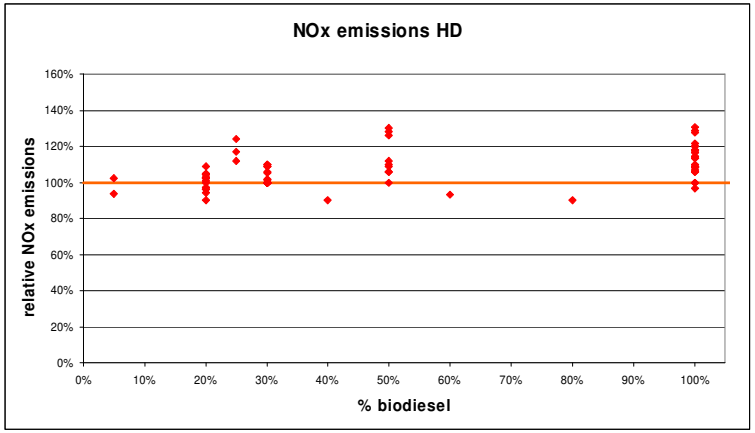


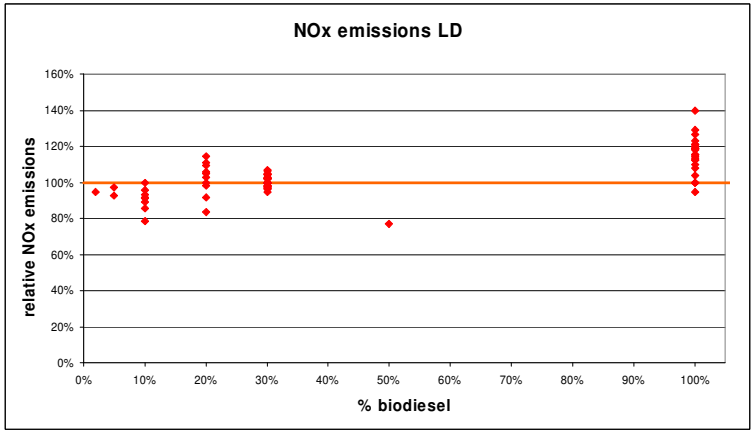


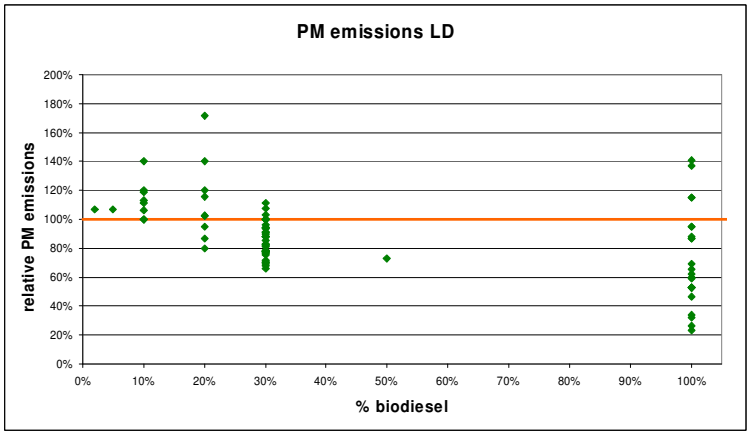


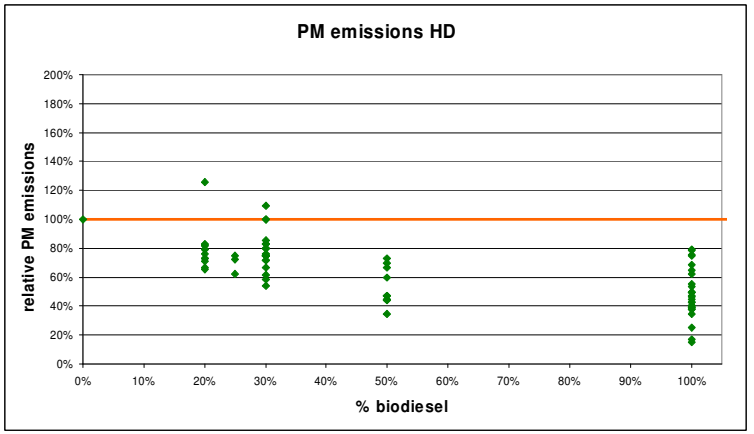


Effects biodiesel (diesel = 100%)

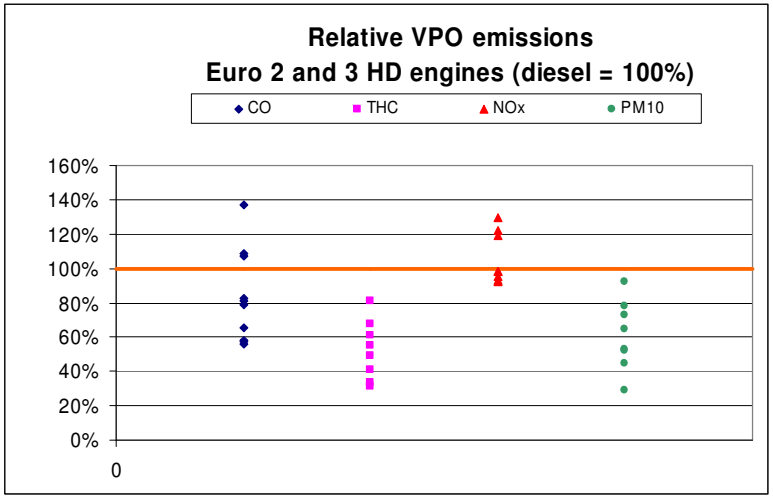


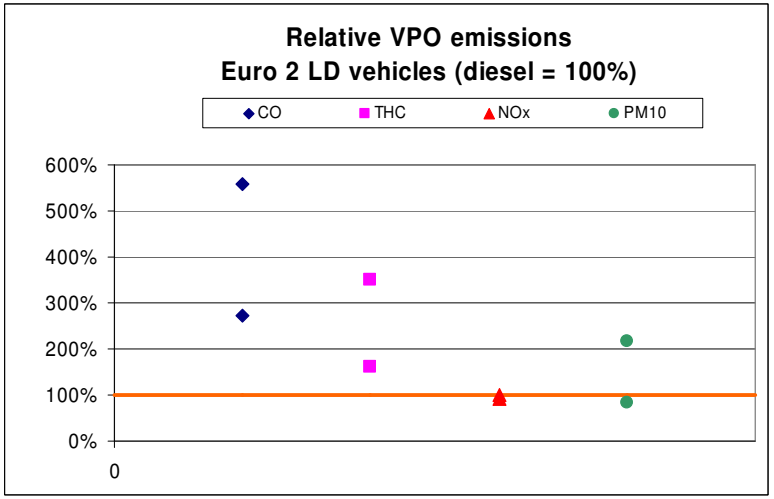




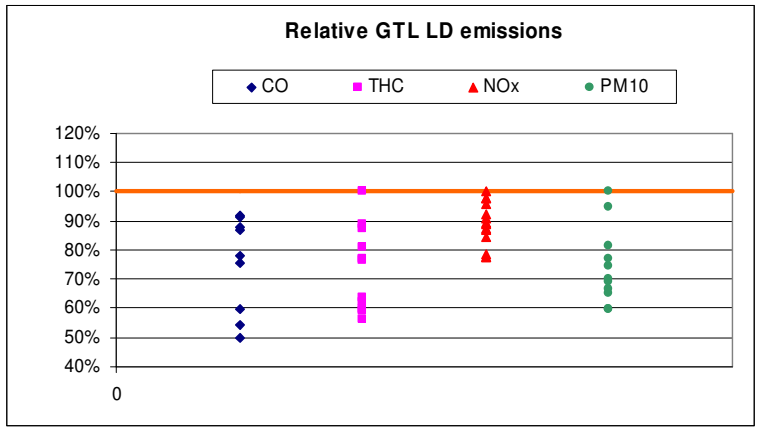


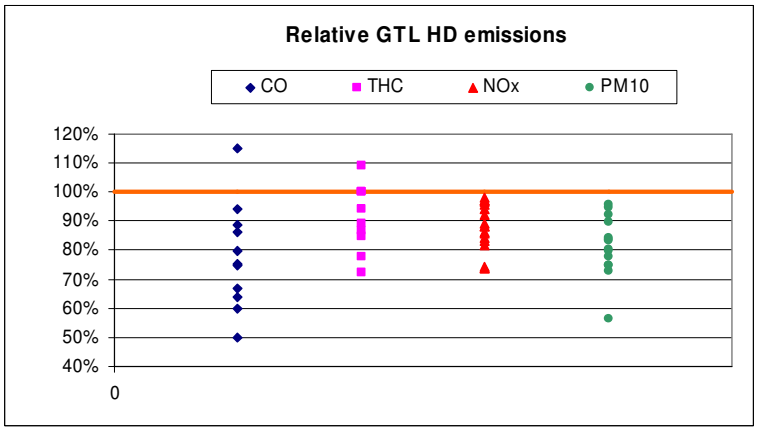
Effects VPO (PPO)





Effects XTL (100% = diesel)





GTL

- Fossil fuel (alkane, paraffine)
- Very good combustion properties (high cetane number)
- Excellent as blend
- Low density (0.77 kg/dm^3)
- Emission advantages of GTL proportional with blend %

Implementation biofuel (blends) in legislation

Low blends petrol and diesel:

- E5 and B5 as standard test fuels for Euro 5:
  phase in 2009-2010

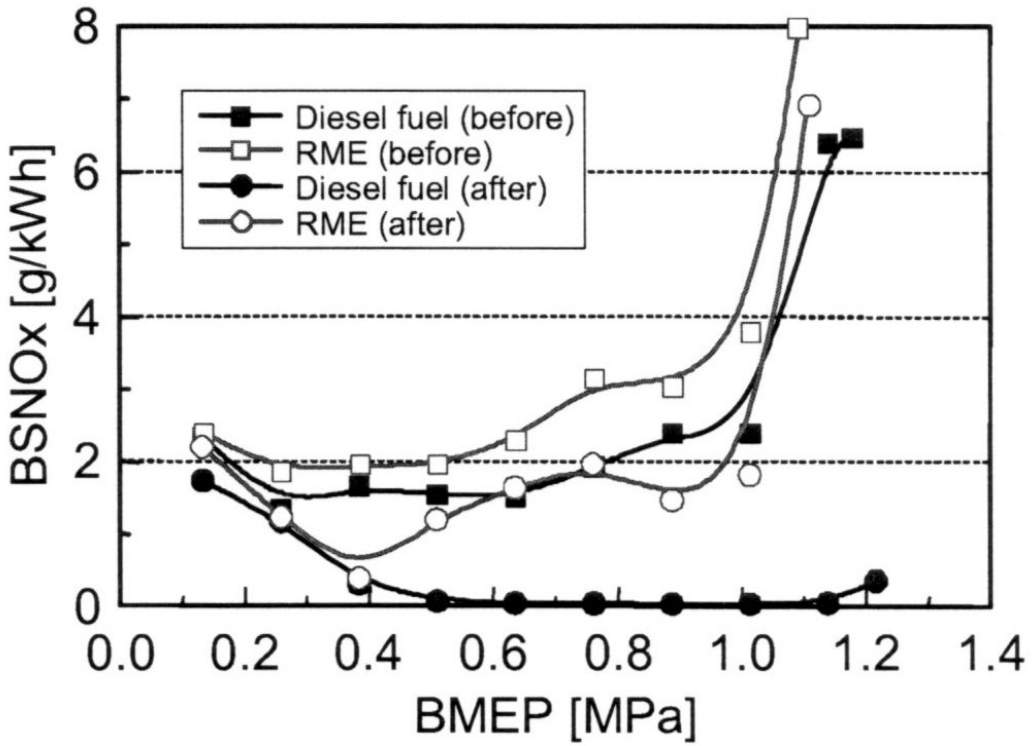
Spark ignition / FFV:

- Euro 5b: test with E85 (resp. E75) for FFV (same as petrol)
  phase in 2011-2012

Compression ignition B100:

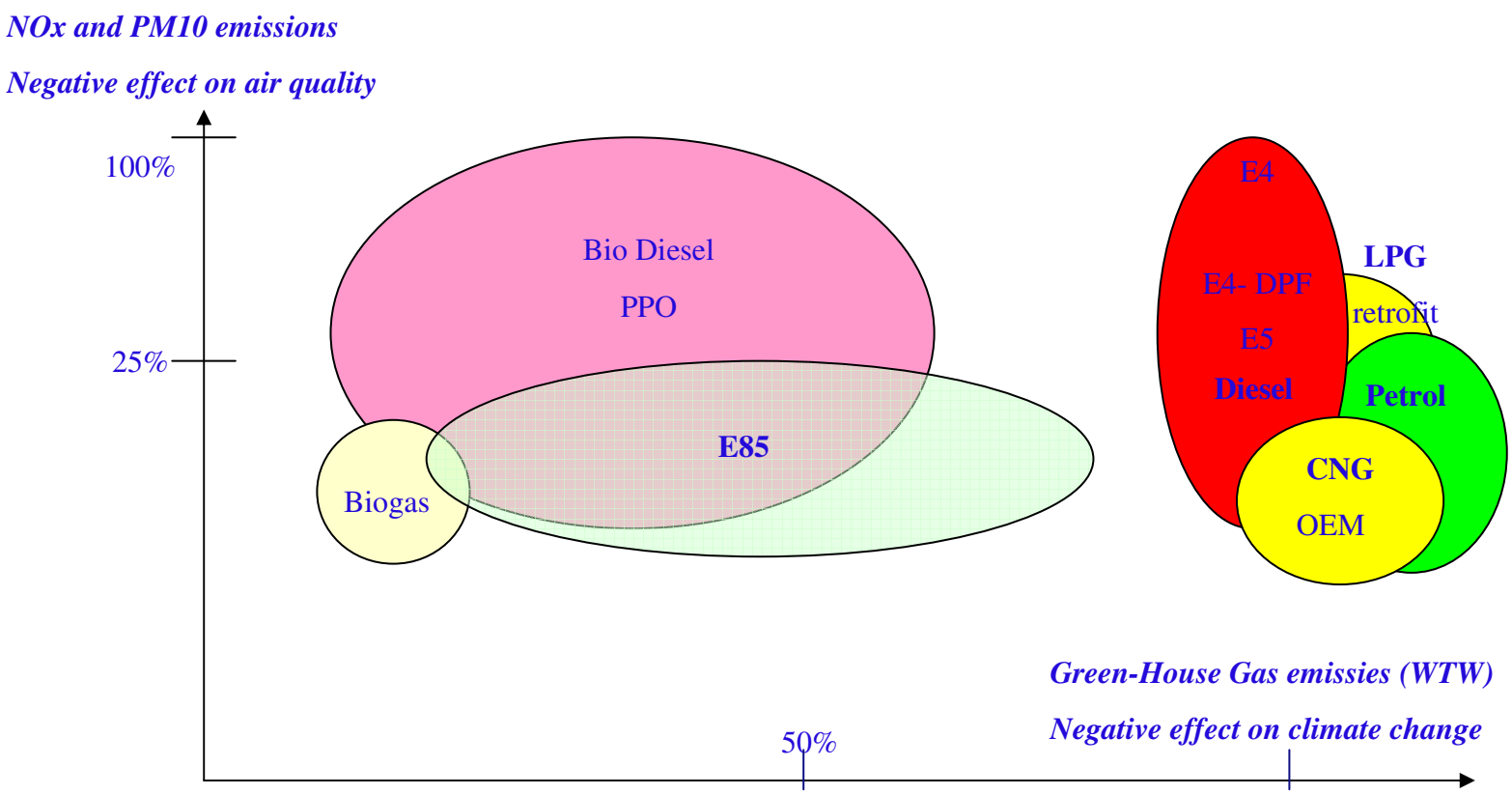
- Test requirements still under discussion

Leveling of NOx with exhaust aftertreatment



NOx emissions before and after catalyst of a turbocharged CI engine with variable EGR and a DPNR aftertreatment system [Kawano 2007]

Impact of biofuels on air quality and climate change (passenger cars Euro 4 to Euro 6)



WTW CO2 from " Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, Annex VII, page (2008/0016 (COD)"

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Conclusions for spark ignition engines (1)

Spark ignition / ethanol:

- E10 suitable for 90-95% of existing vehicles and 100% of future vehicles
- E5 in type approval legislation
- Up to E85 compatible with FFV

Effect ethanol blends on emissions:

- Risks of NOx rise with > E10 for both standard and FFV vehicles
- Lack of real world emissions data
- NOx within limits for FFVs sold after 2012

Conclusions for spark ignition engines (2)

ETBE:

- Bio-ETBE: good compatibility with petrol but limited renewable, high blends not implemented in legislation.
- Probably limited effect on emissions

Biopetrol and butanol: production technology and economics still need to be demonstrated. Good compatibility with existing engine technology.

LPG / CNG:

- Good emission performance with OEM vehicles
- Concerns about emissions for retrofit vehicles

Conclusions compression ignition engines (3)

FAME (biodiesel):
- Biodiesel has substantial impact on engines
- Max 7% FAME (B7) recommended for passenger cars & LD
- Little experience with B20 – B100. Trucks available with adaptation packages. Also as retrofit. Increased maintenance.

Effects FAME on emissions:
HD vehicles:
- B20-B100 on Euro III: 0-70% PM reduction, 0-30% NOx increase
- Possible large NOx increase with Euro IV and V !
- NOx probably all right for Euro VI and later (if closed loop NOx control)

Passenger car and LD:
- B20-B100: PM and NOx variations up to 40% resp. 20%

Phasing in of FAME (blend) in emission legislation necessary !

Conclusions compression ignition engines (4)

XTL: HVO, BTL and GTL

- No adverse effects on maintenance in any blend %. Ideal blend fuel.

With 100% XTL:

- Reduction emissions: NOx (-10%), PM (-20%), HC, CO for Euro III.
- 5-10% loss of power and driving range

VPO:

- more compatibility issues than with FAME -> Not recommended
- Similar effects on emissions

E95: bio-ethanol with ignition improver: suitable for niche markets, good emission performance

Bio-methanol and Dimethyl-ether (DME) require consensus between industry and government. Long development time needed.

Recommendations for fuel mix

- Choose limited number of variants in bio-components:

	SI (petrol)	CI (diesel)
Main Stream	E5 for old vehicles E5 or E10 for main stream E85 for FFV	B5 or B7 for main stream
Niche	CBG for captive fleets	B20 – B100 for adapted vehicles
	Biopetrol if available	HVO, BTL to increase bio share

- High purity desired for compatibility with emission control systems
- Low water content desired for easiness of distribution

Recommendations for R&D

Interaction biofuels with Euro 5 & 6 emission control technology

Emissions measurements necessary (possibly in international cooperation):

- E5-E10 in petrol Euro 5 & 6
- E85 in FFV Euro 4 & 5
- B7 in diesel passenger car
- B20-100 in diesel heavy duty
- Butanol / biopetrol
- Retrofit LPG (CNG)

Evaluation emissions possible toxic components with biofuels & blends

Review results with car and fuels industry

Thank you

- Questions ?

Policy Recommendations

- International cooperation for:
  - policy development
  - development of emissions
  - measurements (real world, in-use compliance)
  - scientific check

- Implement desired blends in legislation:
  Work 20 years ahead:
  For 2030 fuel mix: 2020 vehicles should be suitable
  → start development legislation in 2010

- Well to wheel study on # criteria: climate impact, energy efficiency, land use efficiency, fuel costs, infrastructure, vehicle adaptation (possibly in cooperation with industry)