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Impact of Oxygenates in Diesel Fuel Blends on Engine Emissions and Combustion Properties

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Outline

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- ☐ Technical Data of Test Engine
- ☐ Chemical Analysis
- ☐ Combustion Properties
- ☐ Consumption
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Introduction

- Climate protection conventions (e.g. Kyoto Protocol)
  - ➡ Increased utilization of renewable primary products
- EU: Renewable Energy Directive (RED) and Fuels Quality Directive (FQD)
  - ➡ 10 energ.% biofuels from transport fuel pool
  - ➡ 20% green house gas savings
- Currently known substitutes: FAME, BTL or HVO
  - ➡ Bad quality (viscosity, oxidation stability) for higher blends (FAME)
  - ➡ Inadequate raw material base (BTL, HVO)
  - ➡ Expensive production process (BTL , HVO)
  - ➡ Maximum 7 vol.% FAME approved by car manufacturers

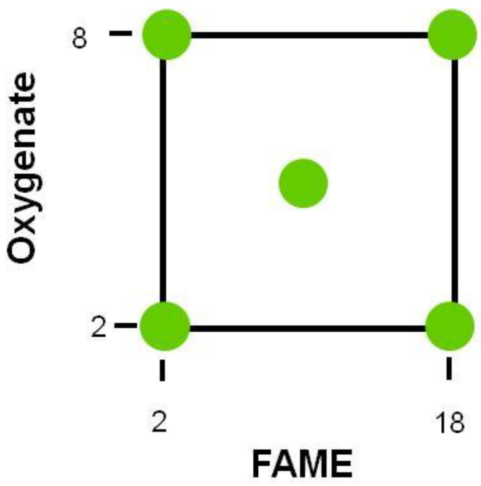
Task Description

- ☐ Investigation of new biogenic oxygenates which fulfill ethical, ecological and economical requirements
  - ➡ Diesel substitute
  - ➡ Interaction with FAME containing diesel

- ☐ Investigated oxygenates
  - ➡ Glyme, Alcohol, Polyether, Tributylcitrat, Levulinat, Valeriat

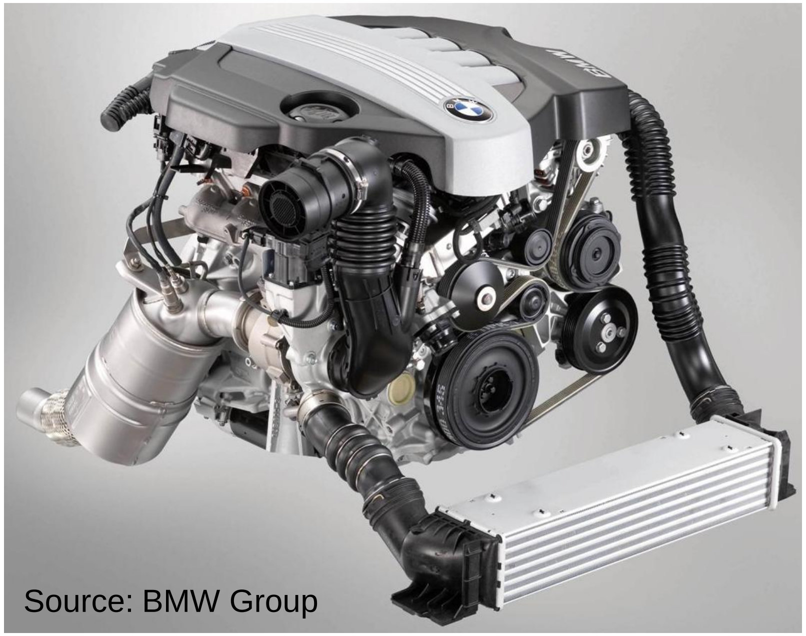
- ☐ Design of Experiments of fuel blends

- ☐ Presented oxygenates
  - ➡ Glyme (Tetra-Glyme)
  - ➡ Alcohol (Butanol)



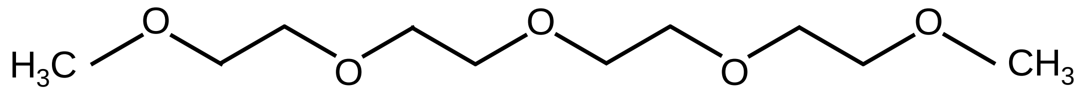
Technical Data of Test Engine

Diesel engine N47 D20 U1 (BMW)	
Cylinder	4 inline
Bore [mm]	84
Stroke [mm]	90
Displacement [cm³]	1995
Compression Ratio	16
Power [kW]	105 at 4000 [rpm]
Max. Torque [Nm]	320 at 1750 [rpm]
Injection System	Common Rail
Turbo Charging	Var. Turbine Geometry

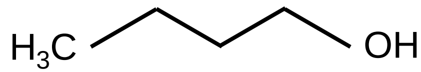

Source: BMW Group

Chemical Analysis

Tetra-Glyme ($C_{10}H_{22}O_5$)



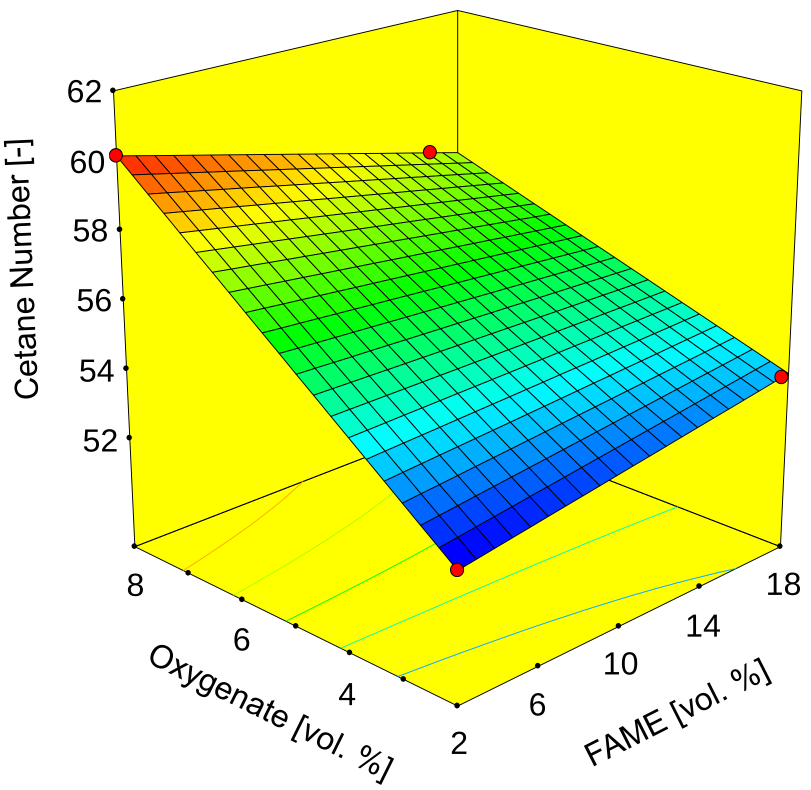
Butanol ($C_4H_{10}O$)

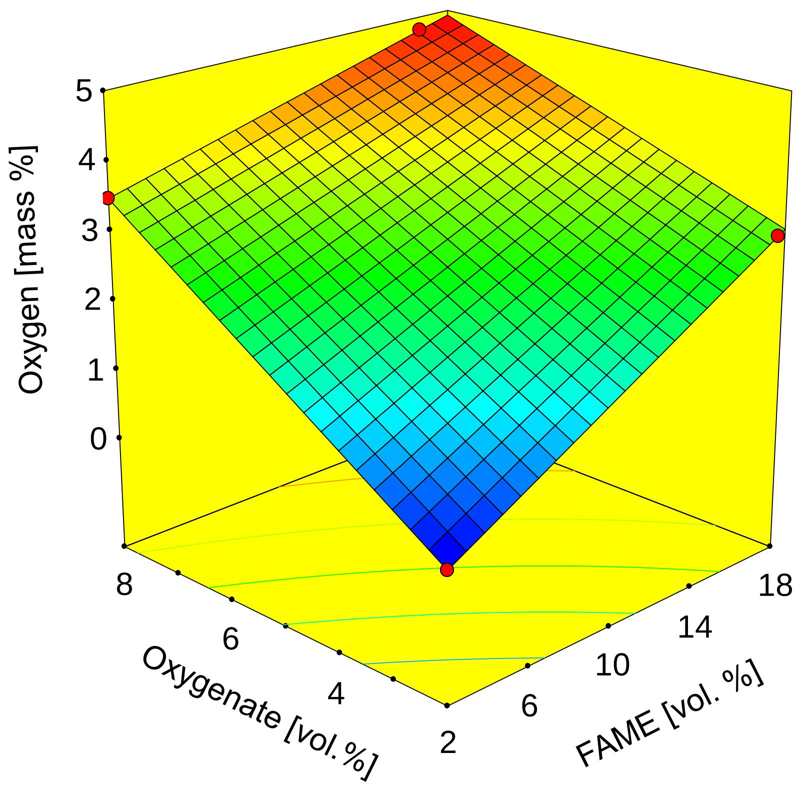


		Oxigenat	FAME	B0	C	H	O	C/H	CN	Density	Flash Point	Heat Value
		[vol. %]			[mass %]			[-]	[-]	[kg/m³]	[°C]	[MJ/kg]
B0	-	0	0	100	86	14	0	6,14	52,1	829	61	43,5
B18	-	0	18	82	84,5	13,5	1,8	6,26	54,1	838,6	64,5	41,955
Glyme	Tetra-Glyme	8	2	90	82,9	13,4	3,5	6,19	60,2	842,9	63,5	41,209
		8	16,56	75,44	81,6	13,1	4,8	6,23	57,8	851	66,5	40,431
Alcohol	Butanol	8	2	90	84,7	13,7	1,6	6,18	48,1	828,2	39,5	42,201
		8	16,56	75,44	82,7	13,5	3,2	6,13	49,9	835,8	38,5	41,083

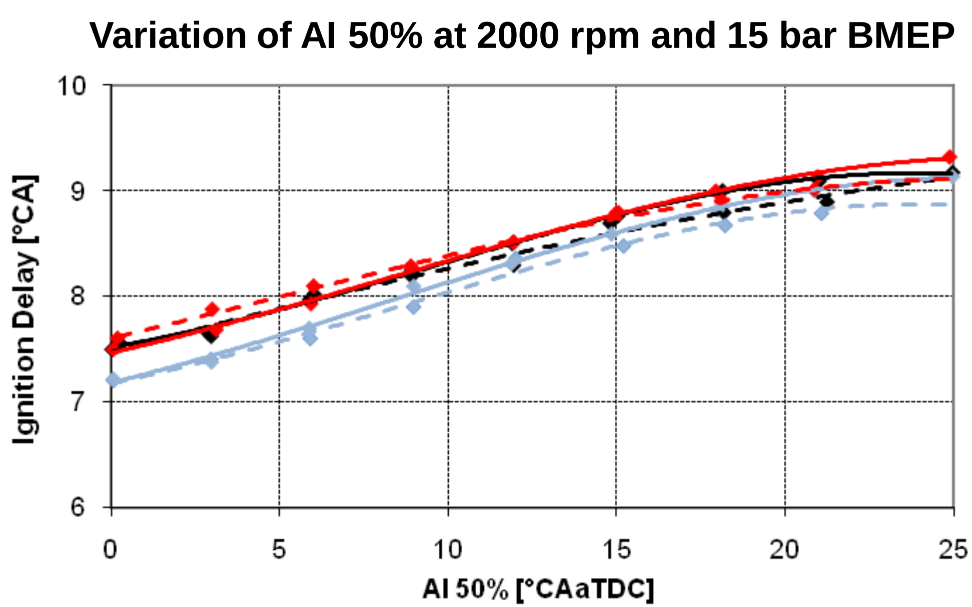
Chemical Analysis

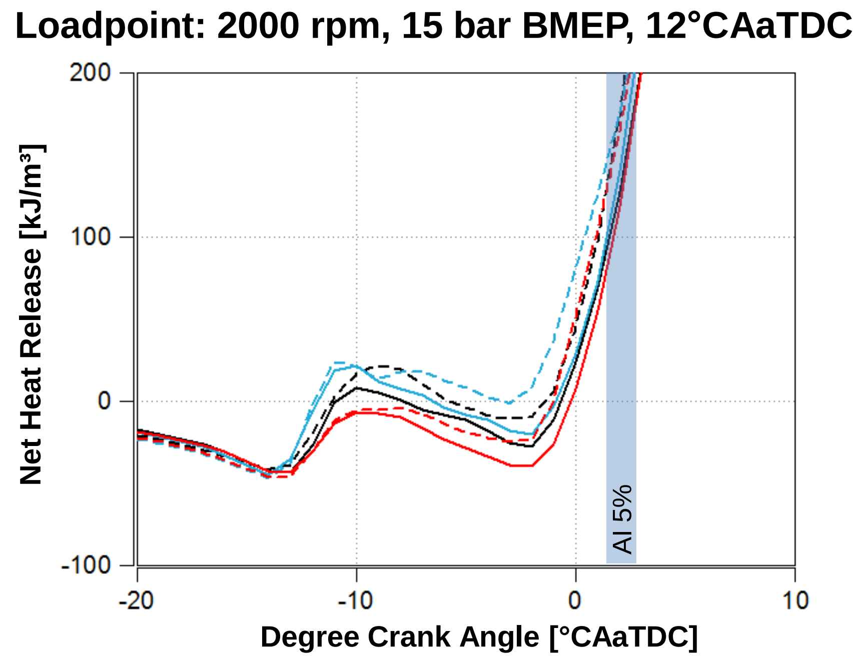
Tetra-Glyme





Combustion Properties





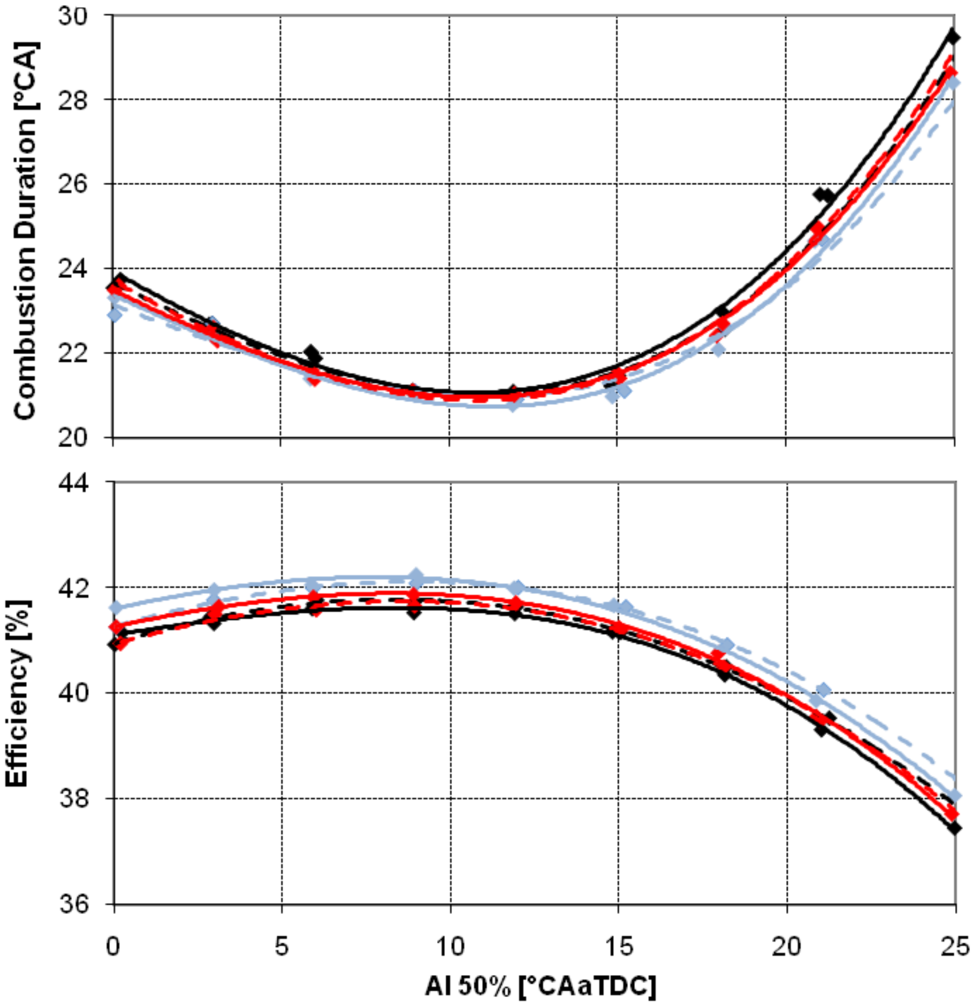
- Additivation of Tetra-Glyme increases CN
  - ➡ higher and faster net heat release
- Additivation of Butanol decreases CN
  - ➡ lower and slower net heat release
- Additivation of FAME has only minor impact on CN and combustion properties

		CN
		[-]
——	B0	52,1
· – –	B18	54,1
——	Tetra-Glyme	60,2
· – –	Tetra-Glyme + FAME	57,8
——	Butanol	48,1
· – –	Butanol + FAME	49,9

Combustion Properties

		CN	O
		[-]	[mass %]
	B0	52,1	0
	B18	54,1	1,8
	Tetra-Glyme	60,2	3,5
	Tetra-Glyme + FAME	57,8	4,8
	Butanol	48,1	1,6
	Butanol + FAME	49,9	3,2

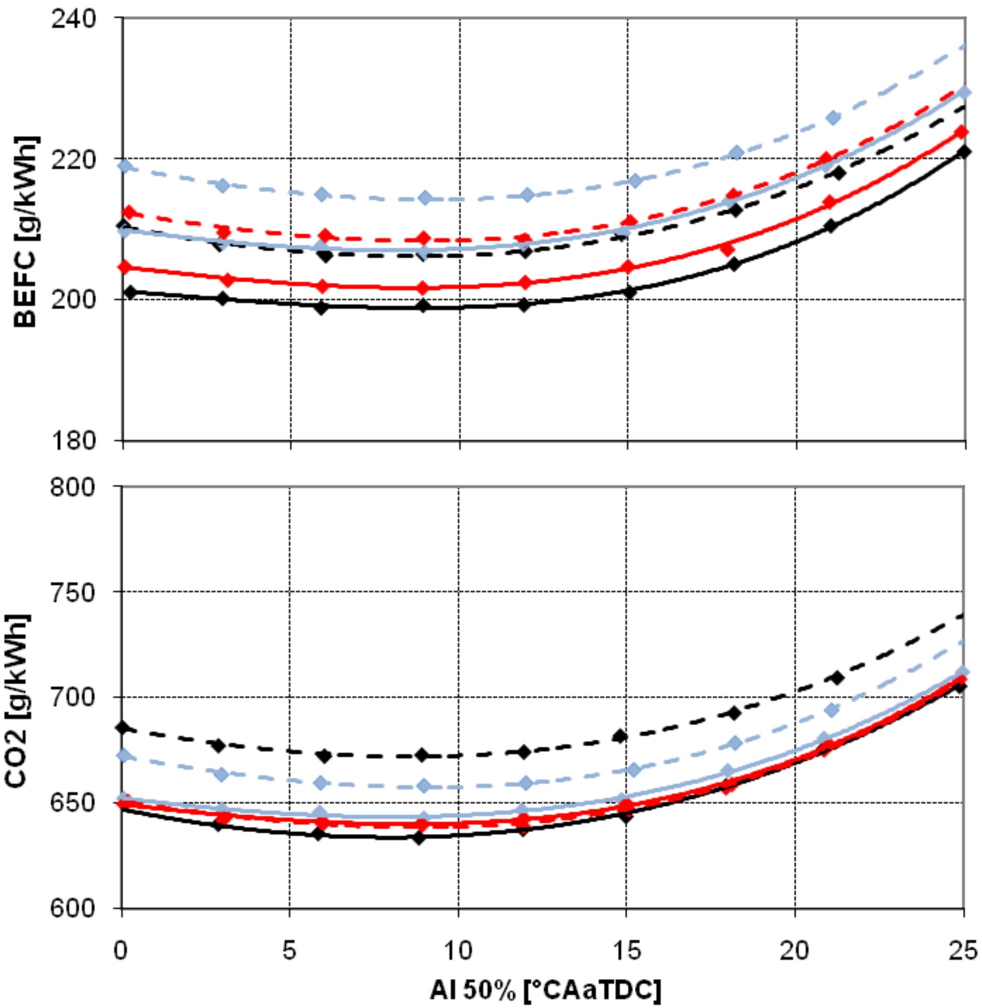
Variation of AI 50% at 2000 rpm and 15 bar BMEP



- Additivation of Tetra-Glyme reduces combustion duration
  ➡ Increase of efficiency
- Additivation of butanol has only minor impact on combustion duration and efficiency
- Additivation of FAME has only minor impact on combustion duration and efficiency

Consumption

Variation of AI 50% at 2000 rpm and 15 bar BMEP

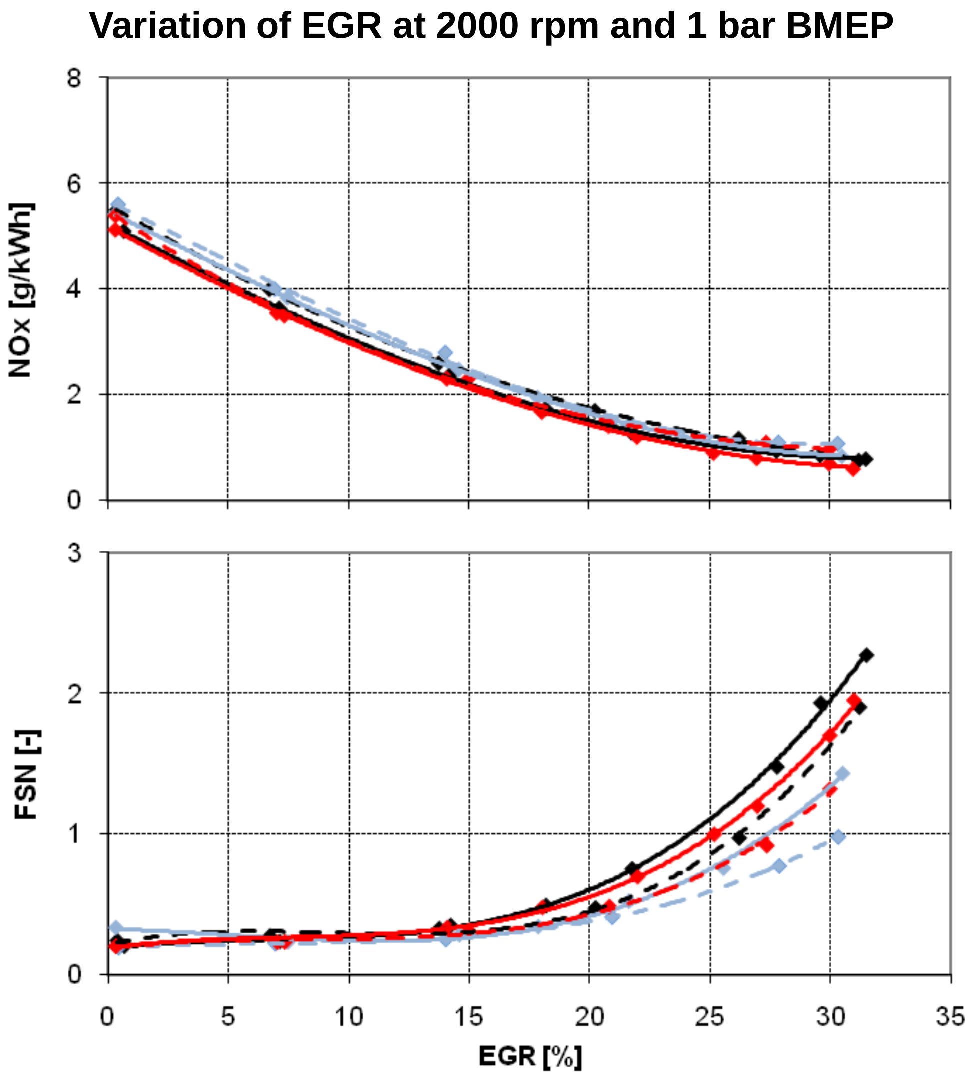


		Density [kg/m³]	Heat Value [MJ/kg]	C [mass %]
	B0	829	43,5	86
	B18	838,6	41,955	84,5
	Tetra-Glyme	842,9	41,209	82,9
	Tetra-Glyme + FAME	851	40,431	81,6
	Butanol	828,2	42,201	84,7
	Butanol + FAME	835,8	41,083	82,7

- Additivation of oxygenate decreases heat value
  - ➡ Increase of gravimetric consumption
- Additivation of FAME further decreases heat value
  - ➡ Further increase of gravimetric consumption
- CO_2-emissions dependent on relation between gravimetric consumption and mass of carbon in fuel blend

Limited Emissions (NO_x and Particle)

		CN	O
		[-]	[mass %]
——	B0	52,1	0
· – –	B18	54,1	1,8
——	Tetra-Glyme	60,2	3,5
· – –	Tetra-Glyme + FAME	57,8	4,8
——	Butanol	48,1	1,6
· – –	Butanol + FAME	49,9	3,2

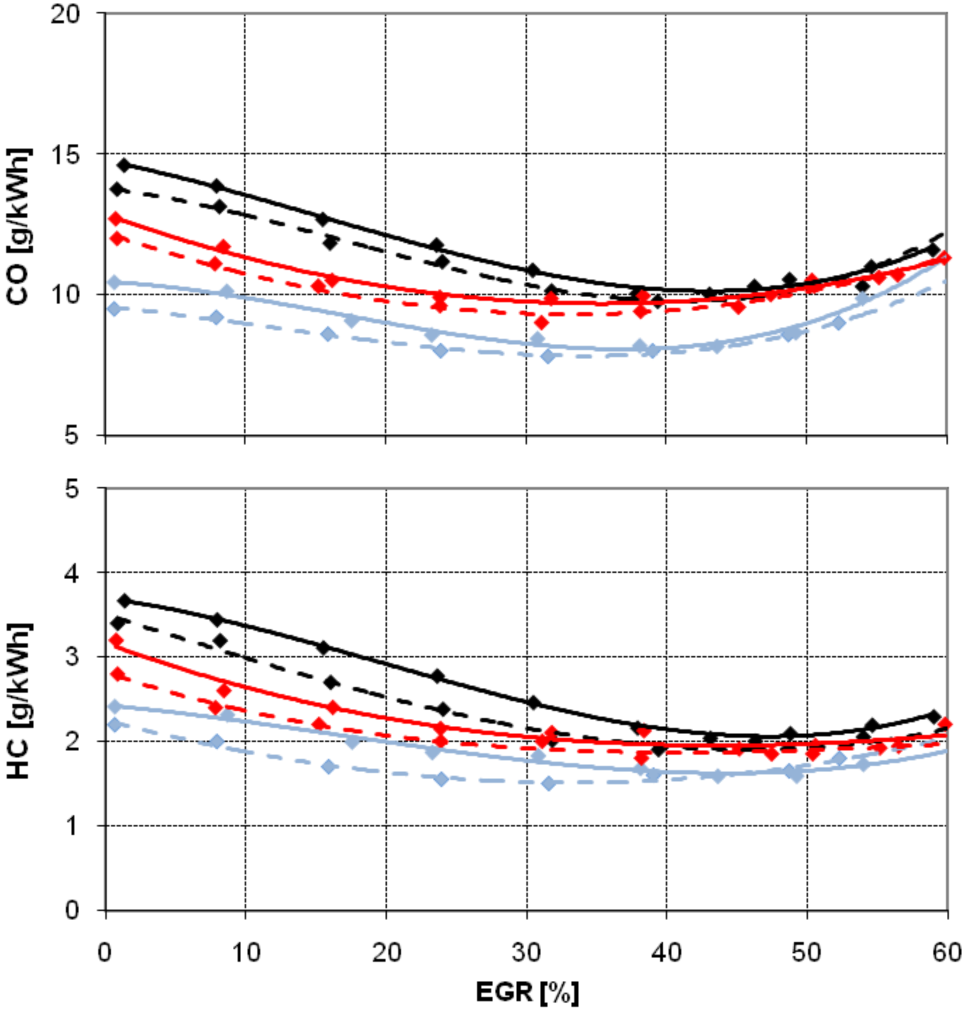


- Additivation of Tetra-Glyme decreases combustion duration
  - ➡ Higher combustion chamber temperatures
  - ➡ Higher NO_x-emissions
- Additivation of oxygenate and FAME increases oxygen content
  - ➡ Reduction of substoichiometric zones
  - ➡ Decrease of particle emissions

Limited Emissions (CO and HC)

		O
		[mass %]
solid black line	B0	0
dashed black line	B18	1,8
solid light blue line	Tetra-Glyme	3,5
dashed light blue line	Tetra-Glyme + FAME	4,8
solid red line	Butanol	1,6
dashed red line	Butanol + FAME	3,2

Variation of EGR at 1500 rpm and 6,5 bar BMEP



- Additivation of oxygenate and FAME increases oxygen content
  - ➡ More homogeneous mixture preparation
  - ➡ Decrease of CO- and HC-emissions

Summary and Outlook

- The additivation of the investigated oxigenates to diesel fuel leads to:
  - ➡ a slight decrease of the combustion duration (Tetra-Glyme)
  - ➡ an increase of the gravimetric fuel consumption
  - ➡ a high decrease of the CO-, HC- and particle emissions

- The additivation of FAME to the investigated diesel-oxigenate blends:
  - ➡ has only minor impact on the combustion properties
  - ➡ increases further the gravimetric fuel consumption
  - ➡ leads to a further decrease of the CO-, HC- and particle emissions

- Biogenic oxygenates deliver an ecological alternative as a diesel substitute and enable a high decrease of the CO-, HC- and particle emissions in combination with FAME. In this context further investigations (Tributylcitrat, Valeriat, Levulinat) will be undertaken.

Thank you for your attention!

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