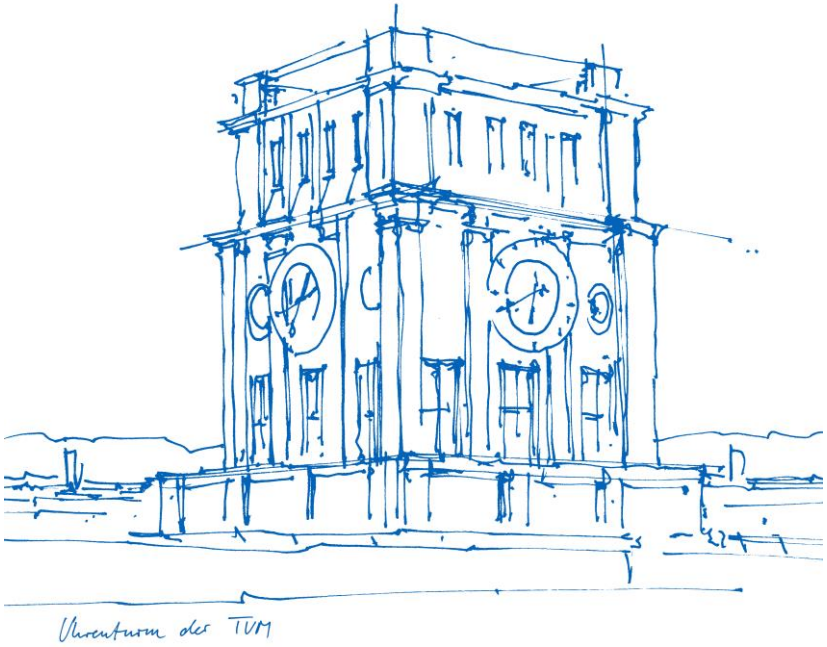
OME Vorstellung

Introduction, Overview

Technical University of Munich

Department of Mechanical Engineering

Institute of Internal Combustion Engines



Institute of Internal Combustion Engines

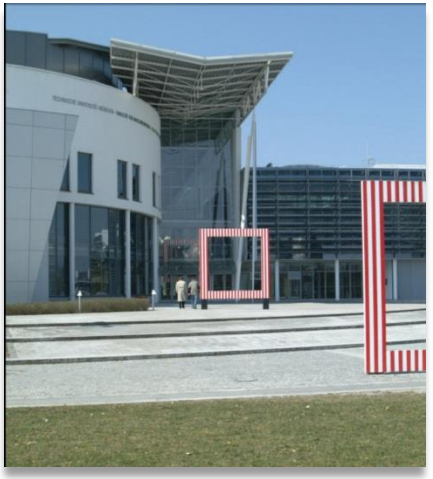
Overview

The Institute was founded in 1936 (Institute for Aircraft Engines and Engines Theory). Experimental and computational analysis of the combustion process is traditionally an essential research focus.

• Head	Prof. Dr.-Ing. Georg Wachtmeister
	Dr.-Ing. Maximilian Prager
	Dr.-Ing. Martin Härtl
• Administration	2 team assistants
• Research / Teaching	32 research assistants
	2 test bed engineers
	1 electrical engineer
	1 post-doc
• Workshop	9 employees

Engine Laboratory Moosach

TUM Campus Garching



Teaching

- Lectures
  - Combustion engines (basics)
  - Engine thermodynamics
  - Engine mechanics
  - Engine application methods
  - Injection technology
  - Engine construction
  - Measurement techniques
  - Fuels for internal combustion engines
- Practical Courses
  - Combustion engines (basics)
  - Electronic engine control
  - Hardware-in-the-Loop

Research Partners

Public funding

FVV

AiF
Ideen eine Zukunft geben

Bundesministerium für Wirtschaft und Technologie

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz

Bayerische Forschungsstiftung

DFG Deutsche Forschungsgemeinschaft

Industrial partners (examples)

MAN

MAN Diesel & Turbo

SET

Modelon

MAN

HATZ DIESEL

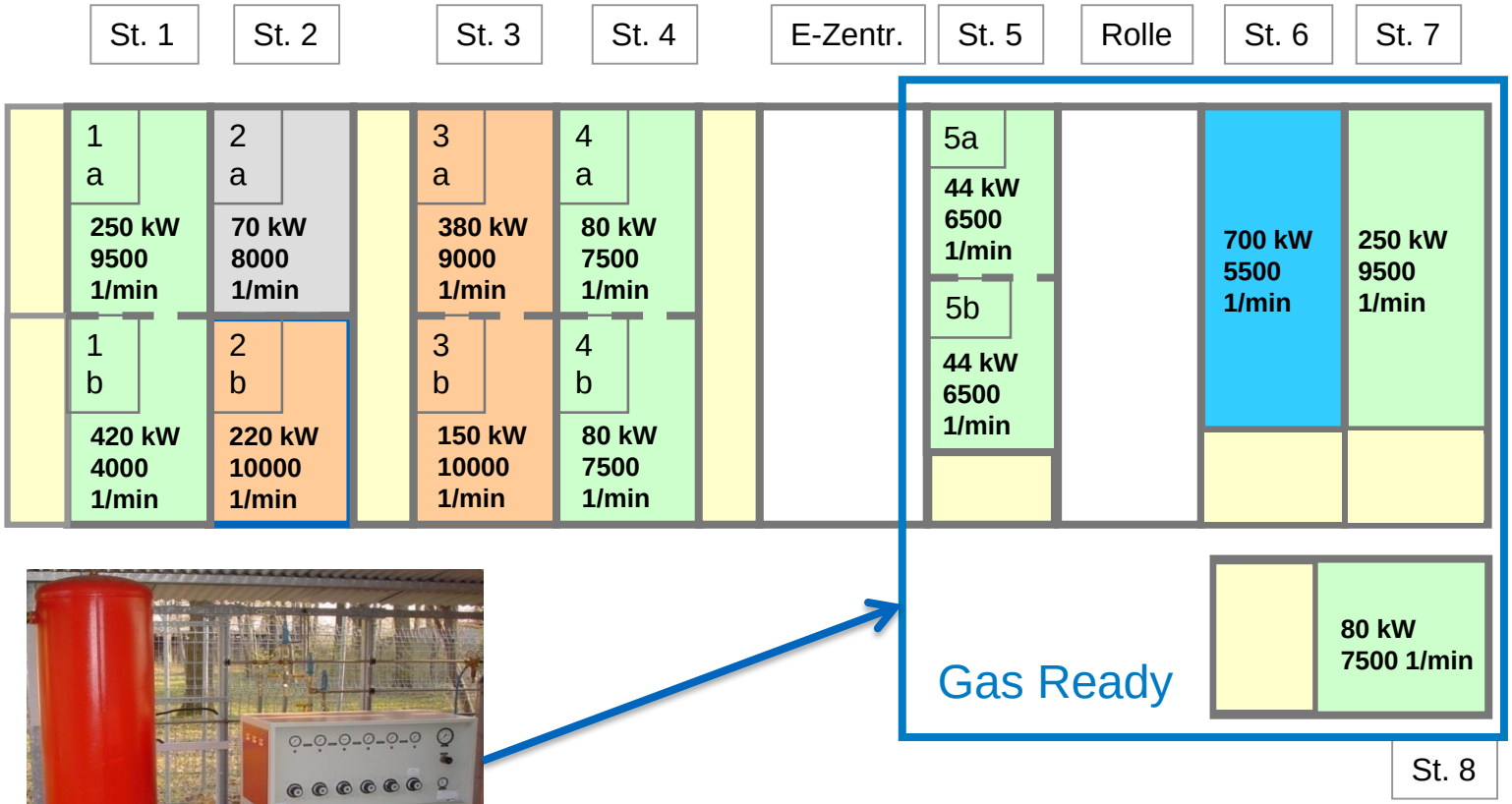
JOHN DEERE

Audi

BMW

HITACHI
Inspire the Next

Test Benches

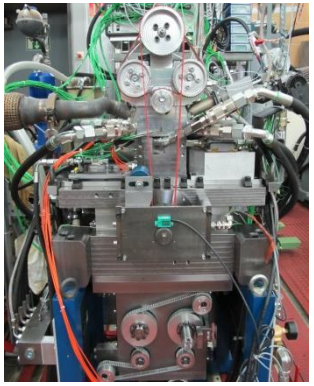


Gas mixing device

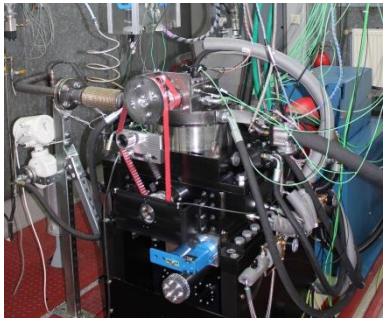
Research Engines

in-house development of single cylinder research engines

combustion development



piston ring movement,
oil transport phenomena



friction measurement
(floating liner)

alternative fuels,
combustion development
(Diesel)

lean combustion,
dual fuel, ...
(Gas)

+ several multicylinder engines

0.5 l (LD) 1.8 l (HD) 4.8 l (Gas)

Workshop

- mechanical workshops
  (turning, CNC- milling, welding,…)
- electronic laboratory
  (calibration, adjusting,…)
- electro-technics laboratory
  (measures, signal systems,…)
- adhesives - and chemical- laboratory
  (hot and cold adhesives , etching,…)

Simulation Portfolio

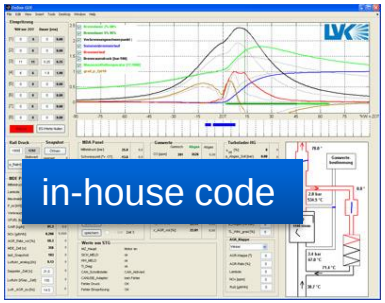
0D

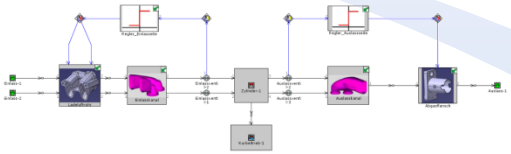
cDyn

GT Gamma Technologies

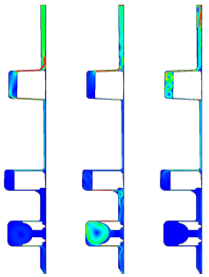
Dymola

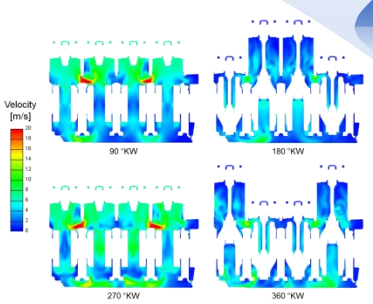
1D



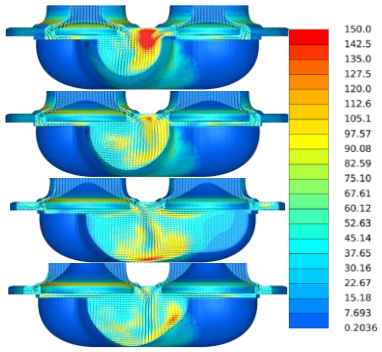


2D



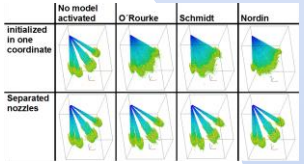


MATLAB SIMULINK



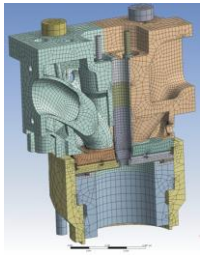
AVL AVL FIRE®

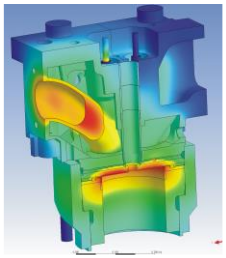
CD-adapco STAR CD®

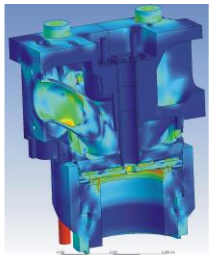


3D

ANSYS CFX®



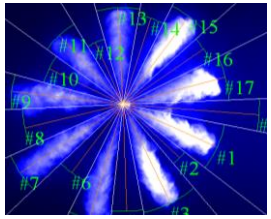


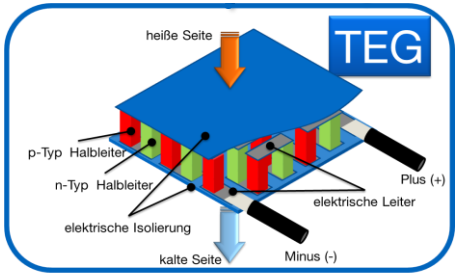


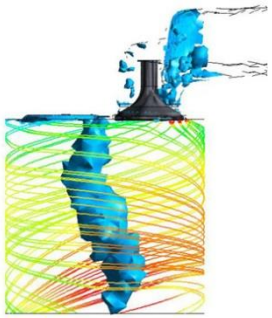
construction temperature stress/strain

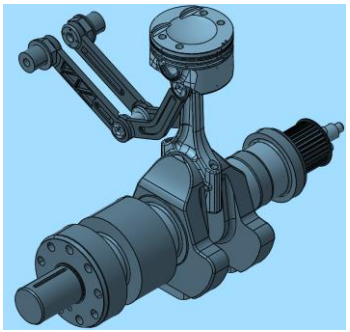
Research Activities

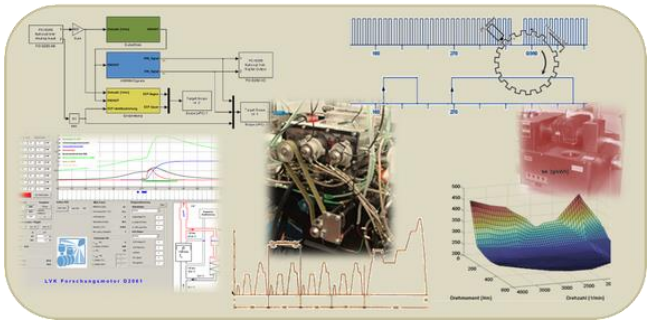
- Injection Technologies
- Energy Management
- Gas-& Industrial Engines
- Mechanics/ Design
- Engine Simulation
- Test Bench Systems











OME-Research Group at TUM

Head of Institute
Prof. Dr.-Ing. Georg Wachtmeister

Senior Engineer
Dr.-Ing. Martin Härtl

Research Assistants:

Kai Gaukel, M.Sc.
Simulation

Patrick Dworschak, M.Sc.
Simulation / Engine Testing

Dominik Pélerin, M.Sc.
Engine Testing

Overview properties

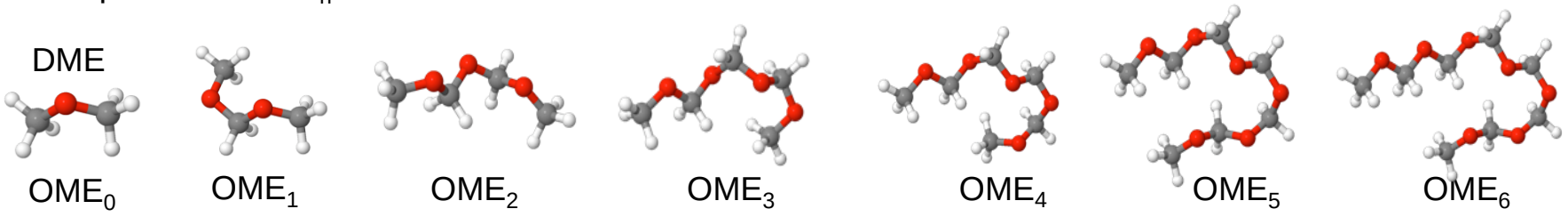
Oxymethylene Ether

- Monomolecular fuel
- Components:
  - CH_3
  - Oxygen
  - Oxymethylene group
- No C-C-bondings
- High oxygen content
- Properties of OME_n

Higher $OME_{n>1}$:

CH_3-O-(CH_2-O)$_n$-CH_3

Diesel OME



Boiling point, cetan number, oxygen content ↑

Calorific value ↓

TUM Research projects

- Dimethyl Ether (DME) Studie (FVV 2009)
  - MTZ 2010, 08, S. 540-542
- Project EREKA (BFS 2010-2014)
  - Emissionsreduktion durch erneuerbare Kraftstoffanteile
- OME1 Experimental testings (2014, 2015)
  - MTZ 2014, 07, p. 68-73; Fuel: 2015, 153; p. 328-335)
- Project „xME“ (BMWi, 2015-2018) -> n = 0, 1
  - Combustion process development for OME1 and DME (Dimethyl Ether)
- Project „OME“ (FNR, 2016-2019) -> n = 2, 3, 4, 5, 6
  - Combustion process development for higher OMEn (n>1)

OME Activities

OME storage at ASGmbh, Neusäß
16 t of OME from China
4 August 2016, visit of LVK

Härtl, Maus, Wachtmeister, Schlögl, Jacob
OME Projects in Germany
25 July 2016, LVK Engine Lab

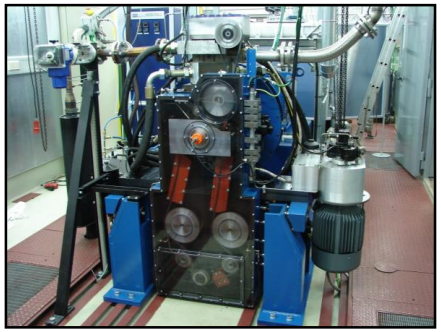
Research Engine

- Single-cylinder research engine (based on the heavy-duty 6 cylinder Diesel MAN D2066)

- Engine specifications:
  - Injection pressure: 3000 bar
  - EGR rate: 50 %
  - Cylinder pressure: 300 bar
  - Displacement: 1,75 l
  - Bore: 120 mm
  - Stroke/bore ratio: 1,3
  - External boost pressure: 8 bar
  - Compression ratio: 16,8
  - Mass balancing I. & II. order (Lanchester)

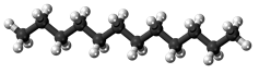
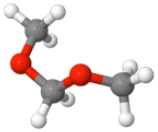
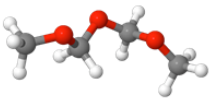
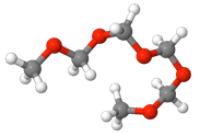
Original Engine Test Setup

HD one cylinder research engine



Fuel properties

Comparison of Paraffinic Diesel Fuel (PDF) / OME1 / OME2 / OME3-6 (mixture)

Parameter	Unit	PDF 	OME1* 	OME2* 	OME3/6** 
Net Calorific Value	kWh/kg	12,2	6,22	5,72	5,22
Density at 15 °C	kg/m³	780	863	970	1068
PDF equivalent	m³/m³	1	1.77	1.71	1.70
Boiling Point	°C	210-302	42	105	157-280
Flash point	°C	> 55	-18	12	69
Cetane Number	-	79.8	29.3	63.5	75.2
HFRR	µm	260 (60 °C)	n.a.	420 (20 °C)	519 (60 °C)
Kinemat. Viscosity	mm²/s	2.92 (40 °C)	0.33 (20 °C)	0.66 (20 °C)	1.19 (40 °C)
Oxygen Content	wt.-%	0	42.1	45.7	47.9

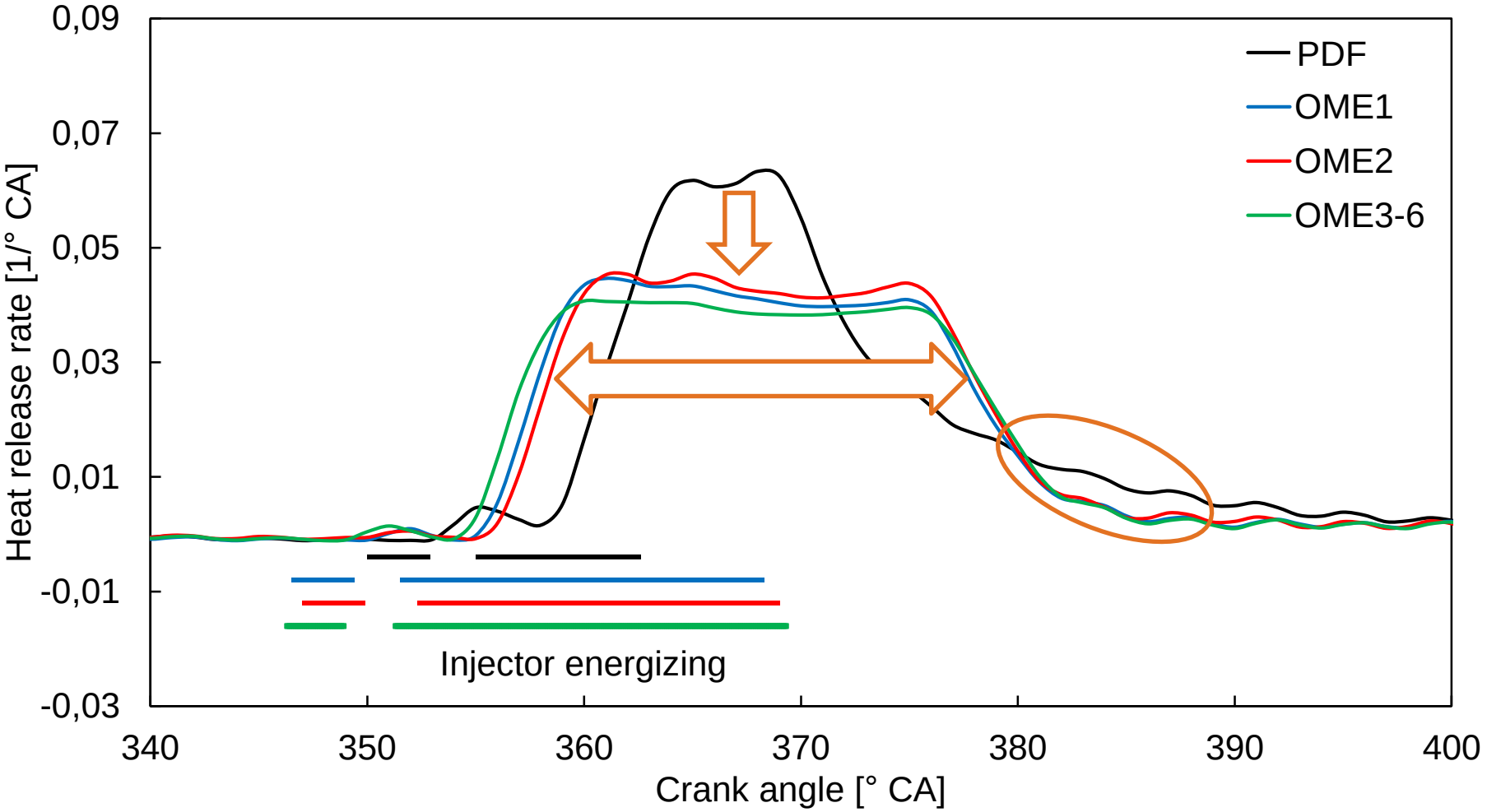
* Additive: 300ppm lubricity improver
** Mix: 43 m.-% OME3; 30 m.-% OME4; 18 m.-% OME5; 7 m.-% OME6;

Engine tests: medium speed & load

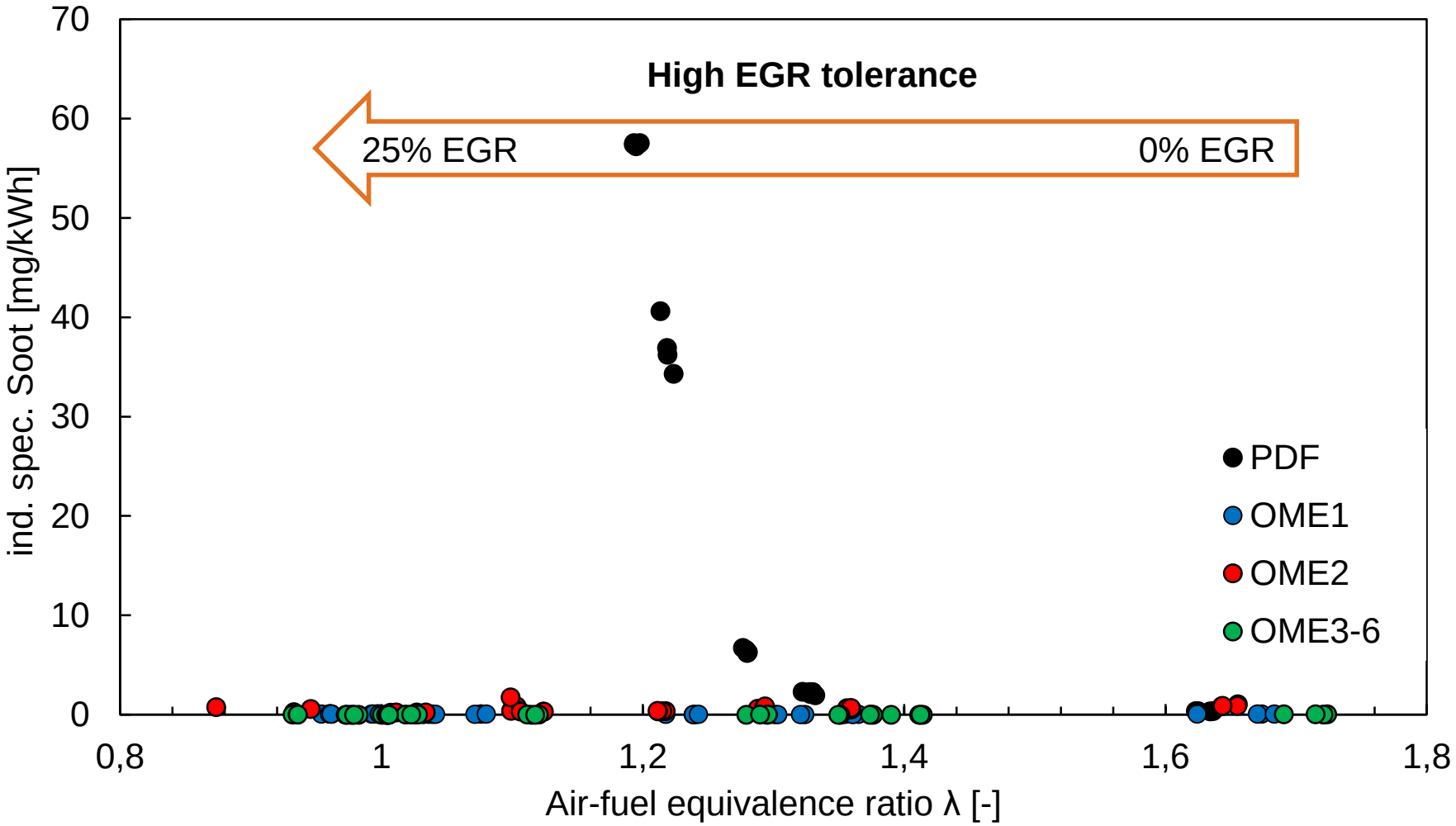
- Tested fuels:
  - OME1
  - OME2
  - OME3-6 (mixture)
  - PDF (reference fuel)

- Operating conditions:
  - Indicated mean eff. pressure: imep = 13 bar
  - Engine speed: n = 1200 min^{-1}
  - Rail pressure: p_{rail} = 1800 bar
  - Boost pressure: p_{boost} = 1.94 bar
  - Injection strategy: Pre-injection (5 °CA before MI, 0.35 ms) & main injection
  - Center of combustion: 8°CA after FTDC
  - EGR-sweep: Step-by-step increase → NO_x ↓

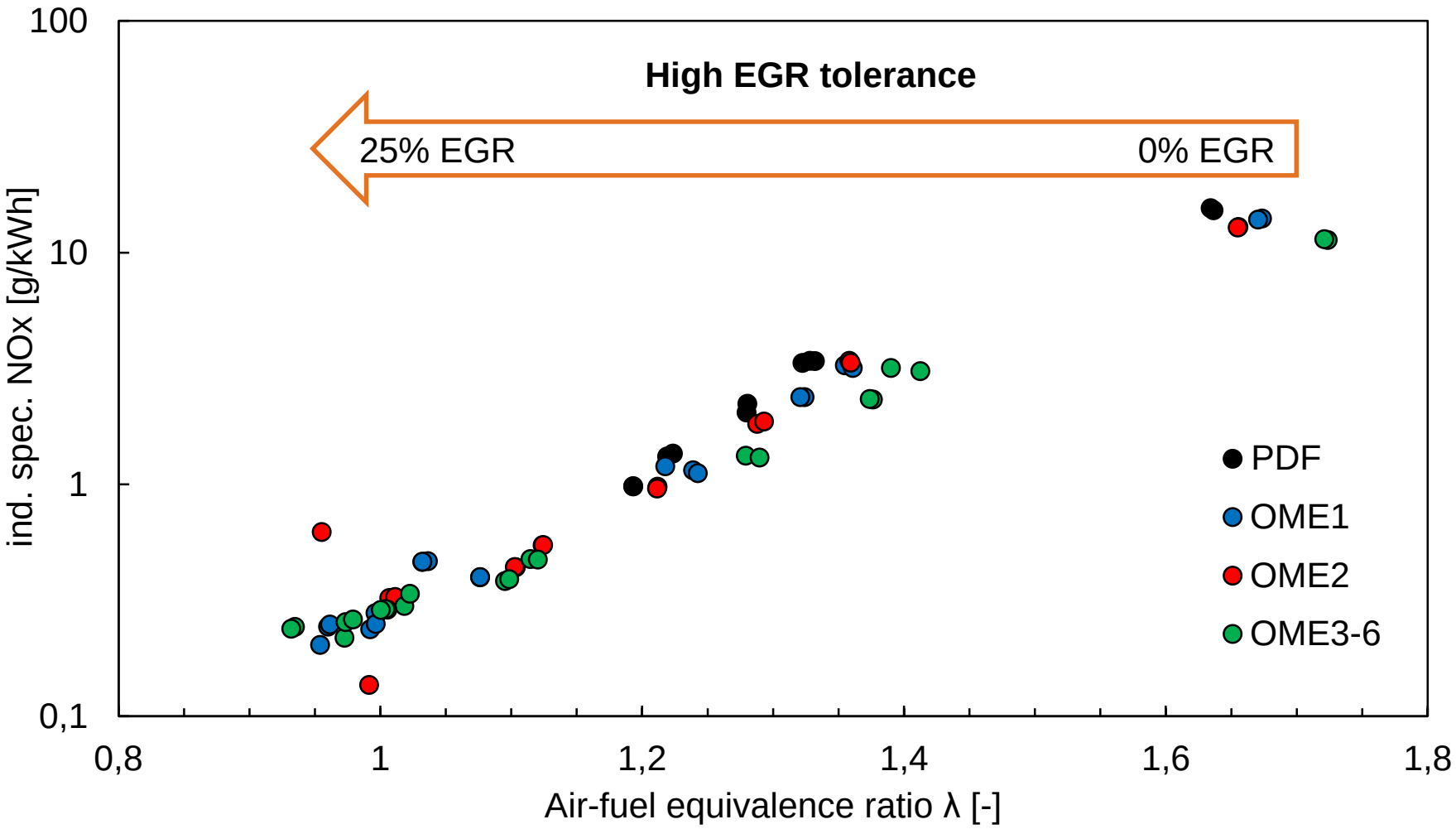
Combustion (no EGR)



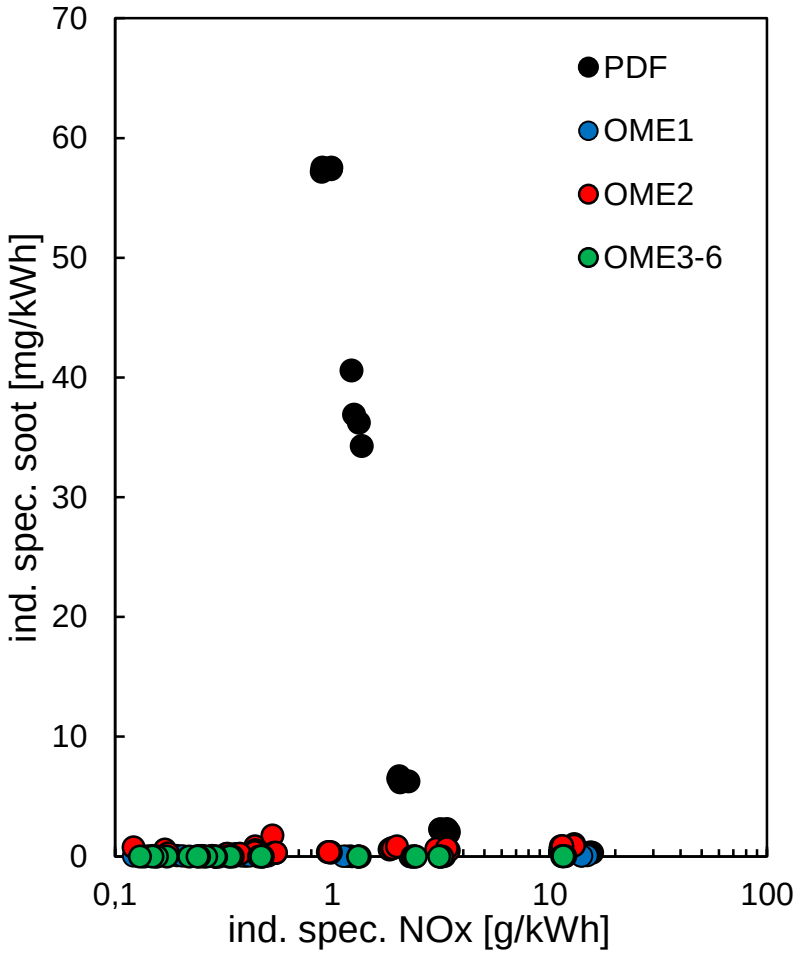
Soot emissions

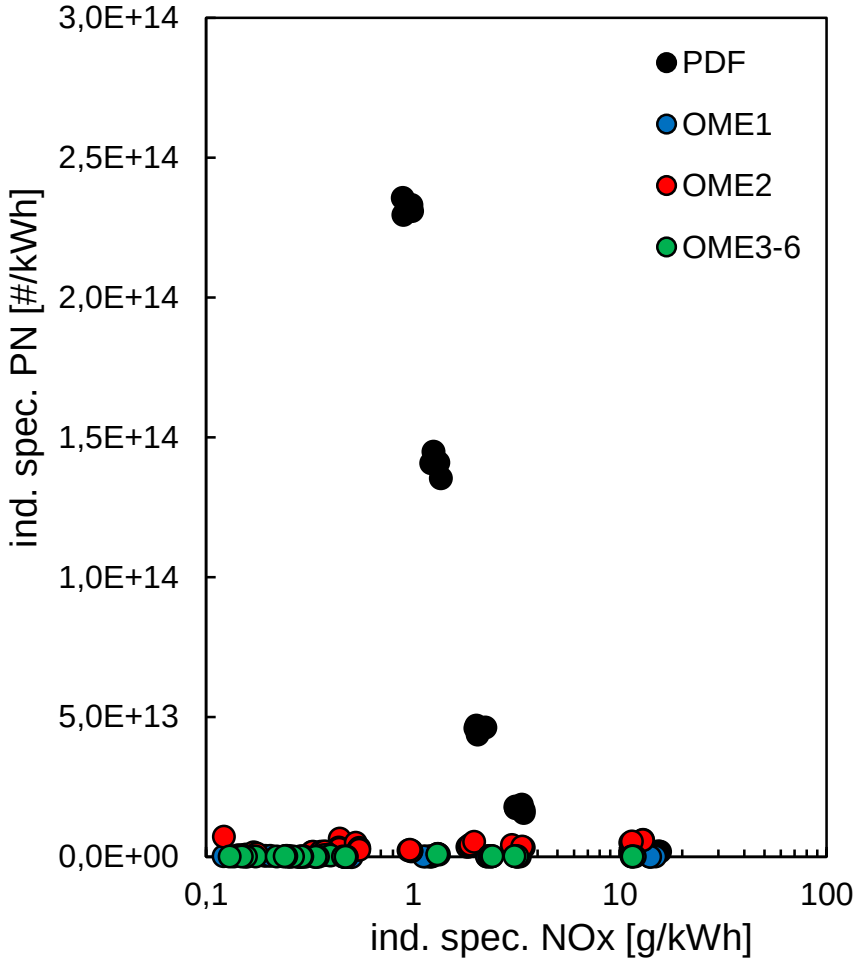


NO_x emissions

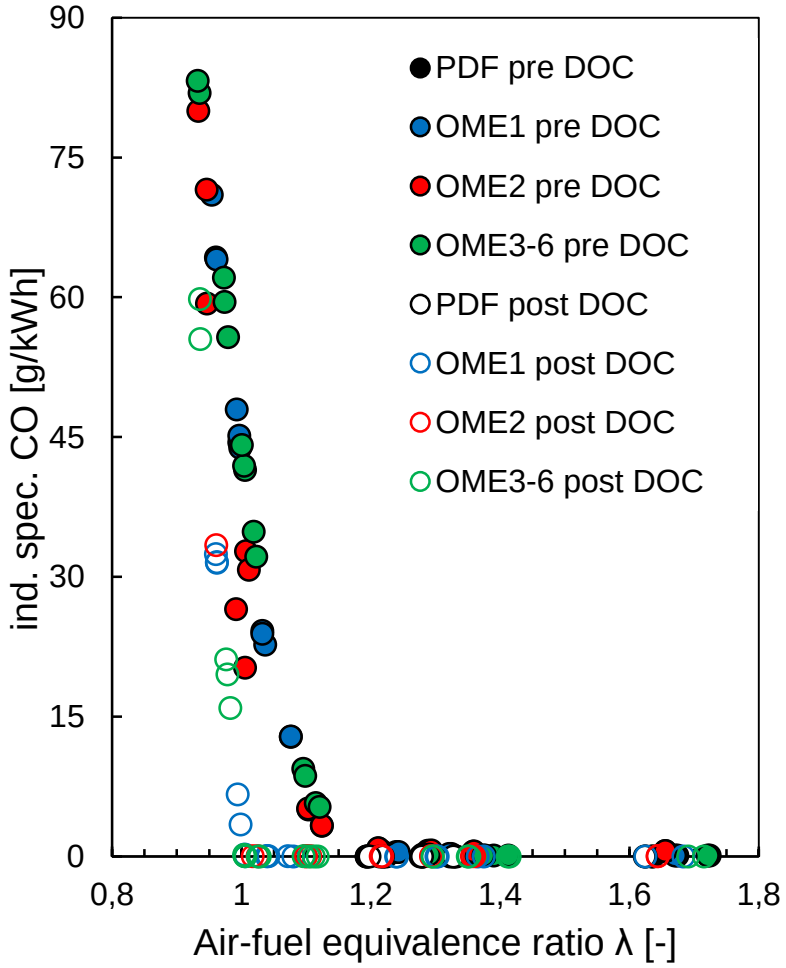


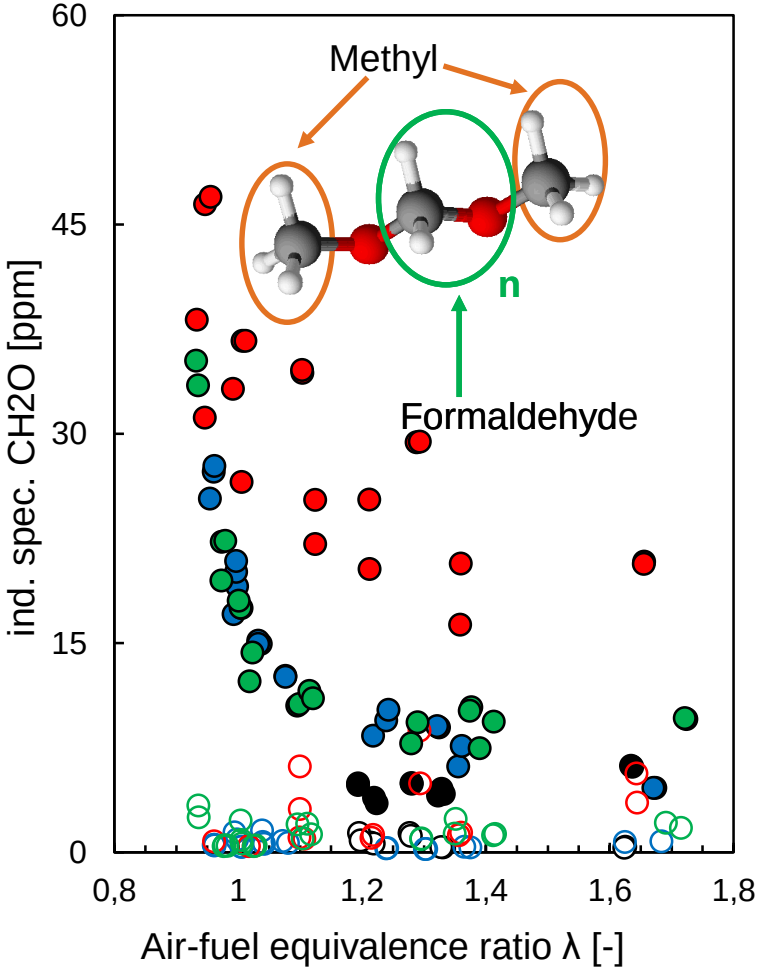
Soot - NO_x trade-off



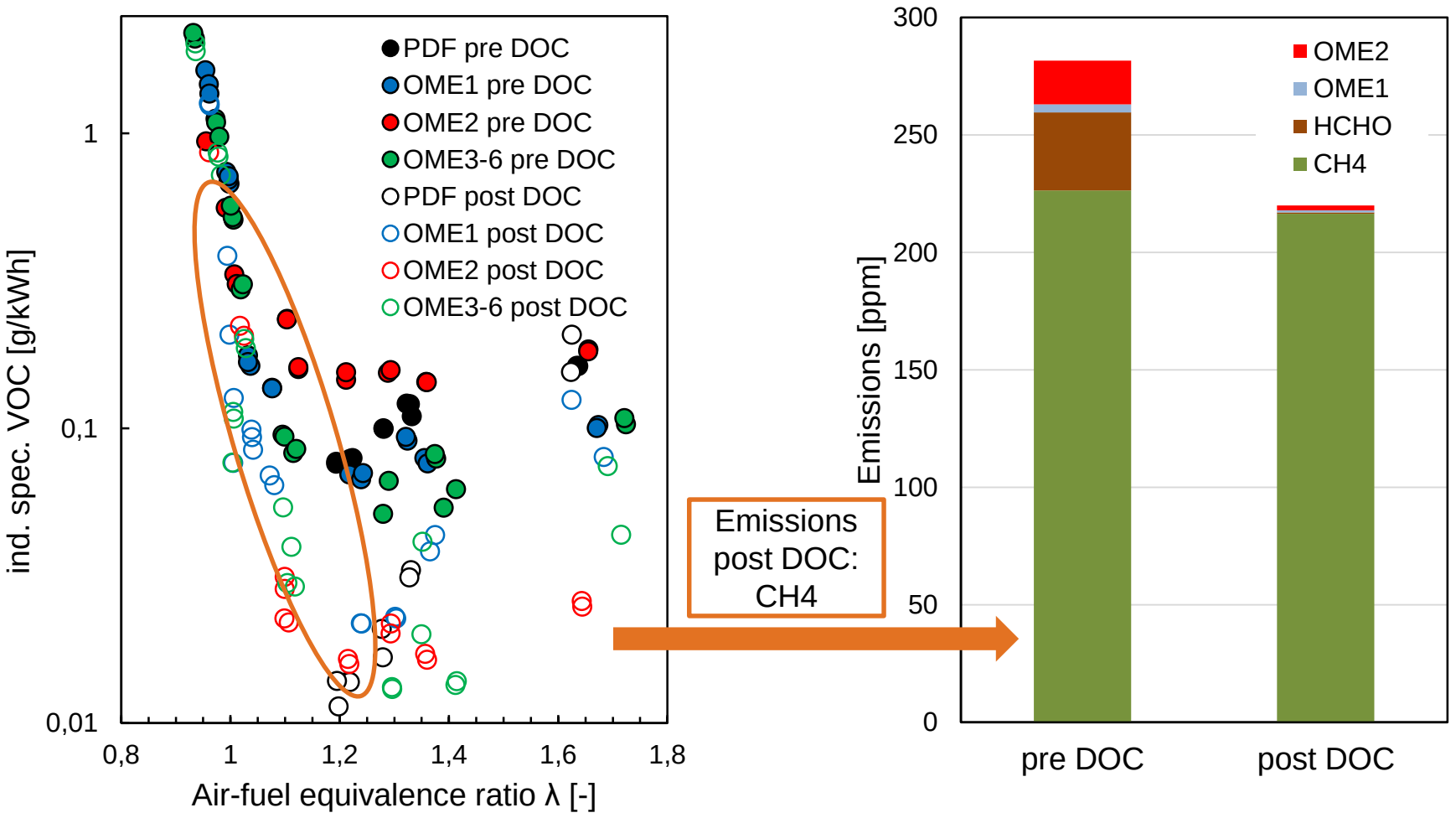


CO- and formaldehyde (CH_2O) emissions

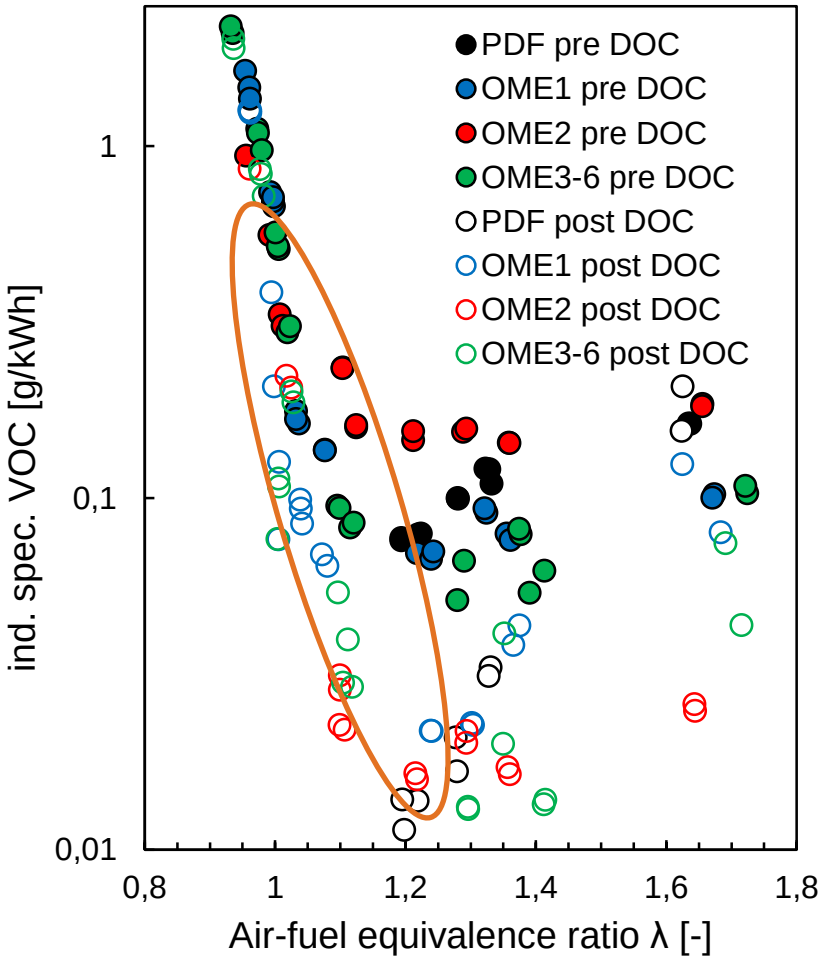




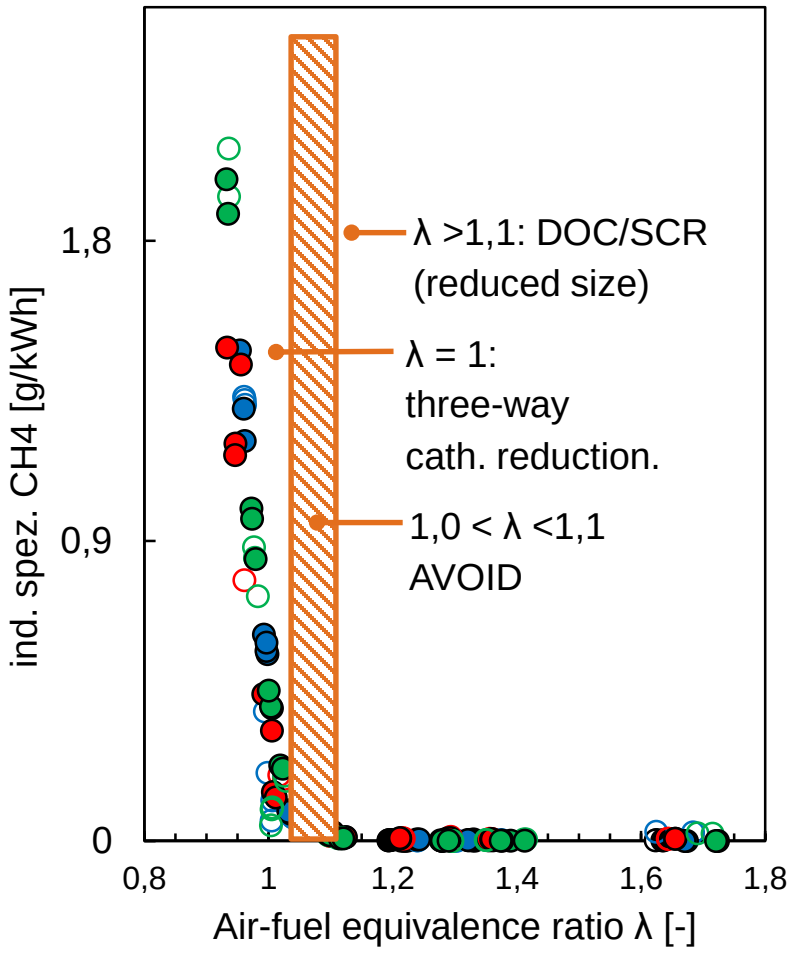
VOC and methane emissions



VOC and methane emissions

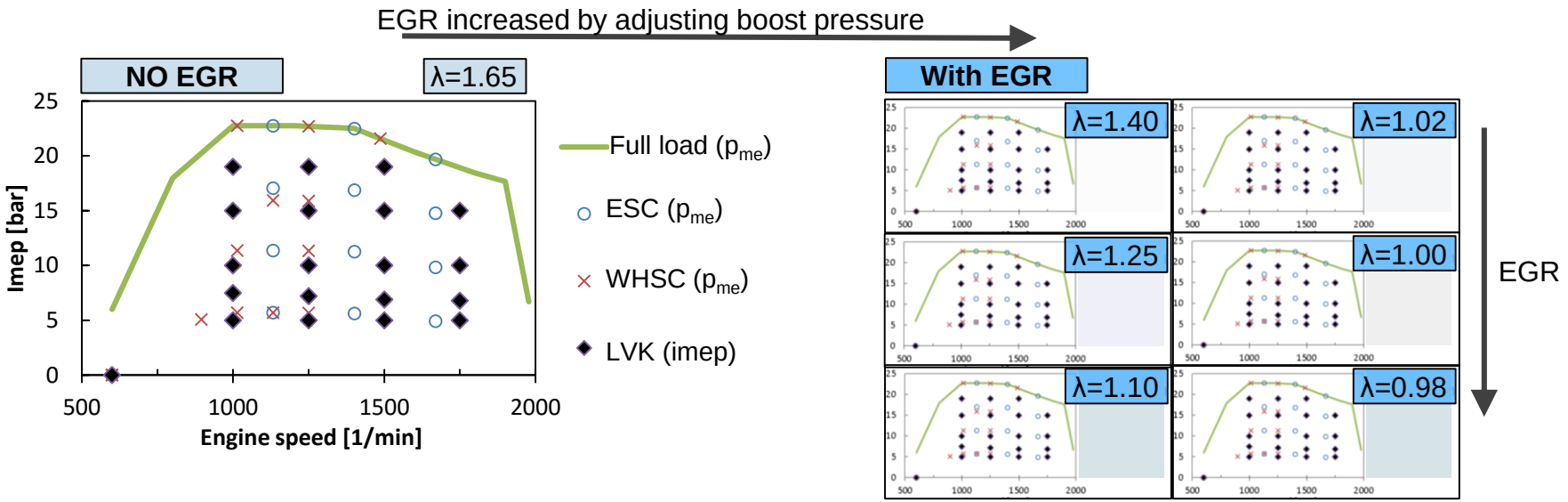


Strategy for exhaust gas aftertreatment

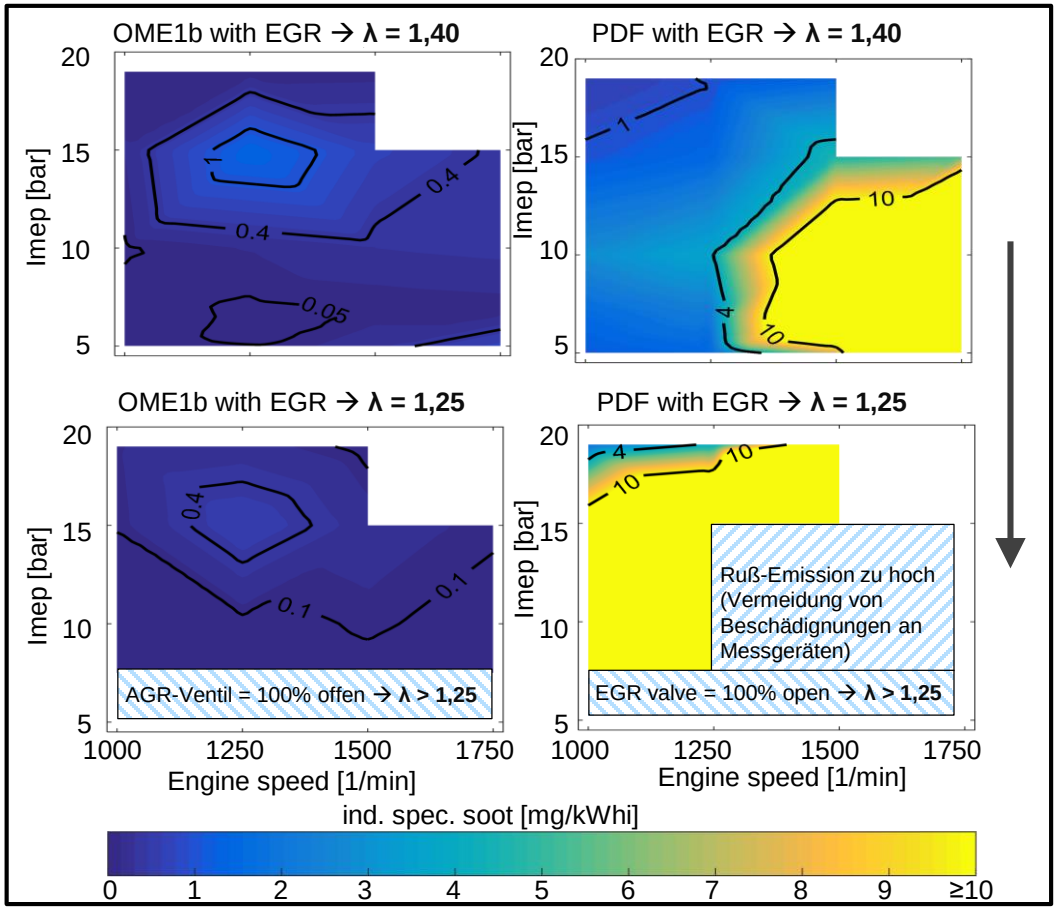


Engine map investigation

- Tested fuels:
  - OME1b (additives for CN and lubricity)
  - Paraffinic Diesel Fuel (PDF) as reference
- Operating conditions:
  - Injection pressure: p_{Rail} = 1800 bar
  - Injection strategy: pre-injection (5 °CA before MI, 0.35 ms) & main injection
  - Center of combustion: 8°CA after FTDC
  - Boost pressure: variable → λ = 1.65 for every operating point (without EGR)



Engine map investigation



PDF

- soot emission increase significantly
- λ = 1,40:
  - soot > 10 mg/kWhi (EURO VI) only at low loads and high speed.
- λ = 1,25:
  - soot < 10 mg/kWhi only at high loads and low speed.

OME1b

- Low soot emissions within the entire engine map, independent of speed, load and EGR rate.