Science4Fuels
OWI
an der RWTH Aachen

Biofuels for combustion applications

Research efforts at OWI

Dirk Möntmann, WORKSHOP ON TECHNOLOGIES FOR BIOFUEL HYBRID MICRO GAS TURBINES, 25.09.2024

Agenda

- Timeline
- „Bio“-Fuels tested @ OWI
- Fuel properties
- Selected results from the combustion
- Summary and outlook

Timeline

2001
Sulphur
< 1000 ppm
(standard)
< 50 ppm

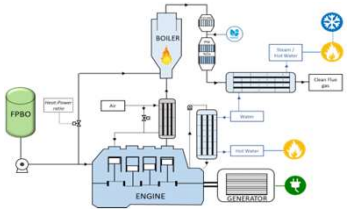
2010

HVO for
domestic
heating

2015

Residue 2 Heat

FPBO for
domestic
heating



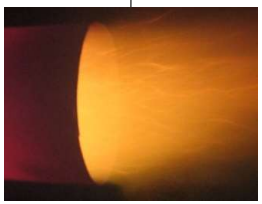
2022

Fit4Micro

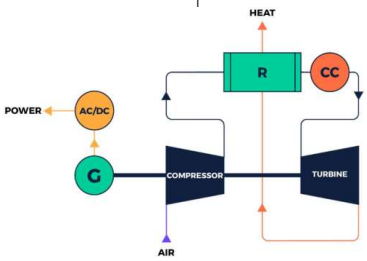
HPO fueled
micro turbine

2004
deposition
formation in
premixed
combustion with
5% FAME

2011 Flex³
modulating burner
7 kW – 15 kW
Fossil- & biofuels

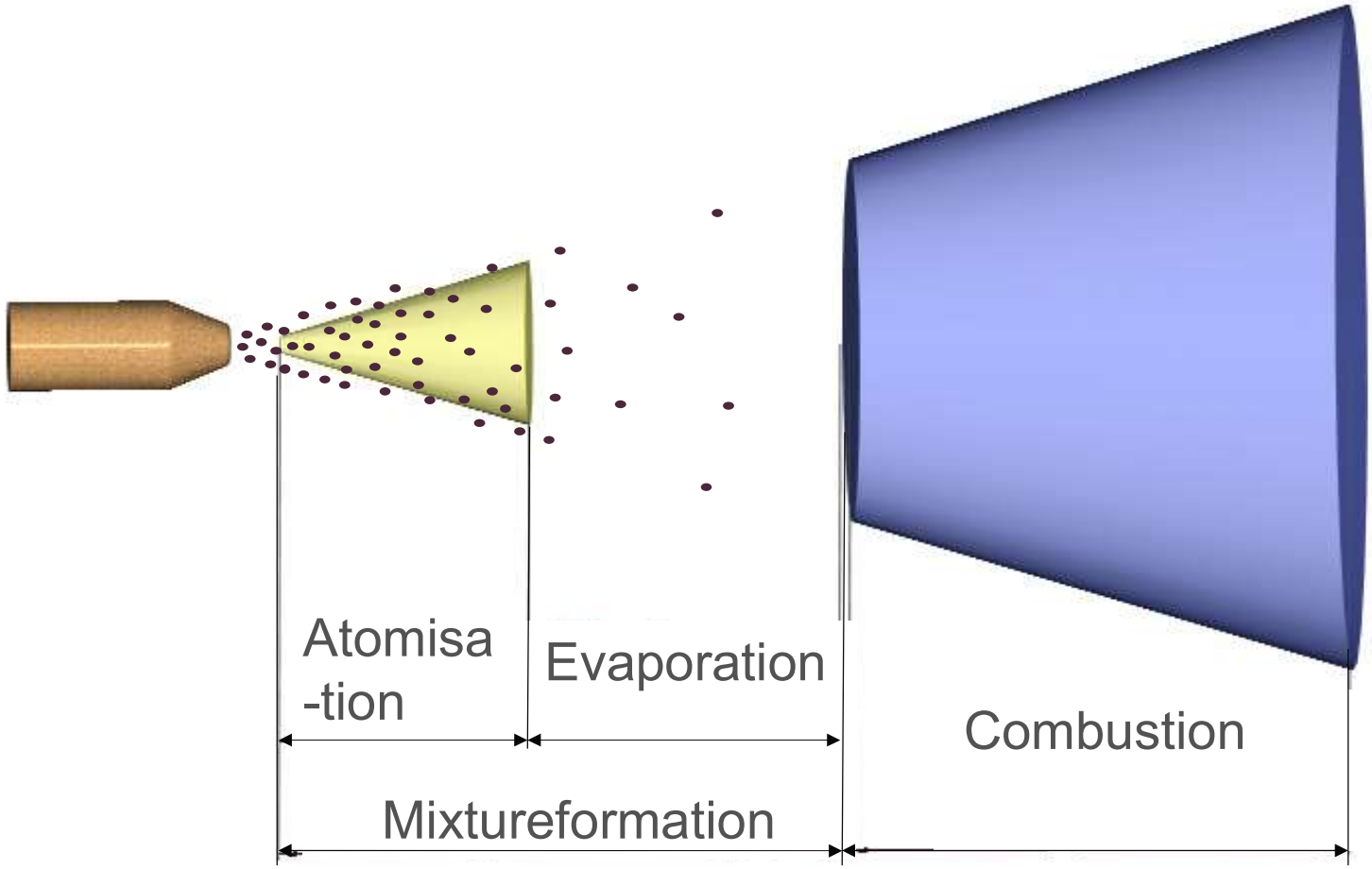


2019
SmartCHP



FAME: Fatty acid methyl ester, HVO: Hydrogenated vegetable oil, FPBO: Fast pyrolysis bio oil

Combustion of Liquid Fuels



Liquid Fuels

- Domestic heating oil (referrence)
- Esterified vegetable oil (ME)
- Hydrogenated and isomerised vegetable oil (HVO)
- Destillation residues
- Residue from UCOME production
- Scrap tires pyrolysis oil (APO)
- Fast pyrolysis bio oil (FPBO)
- Hydrogenated pyrolysis bio oil (HPO)


HEL


HVO

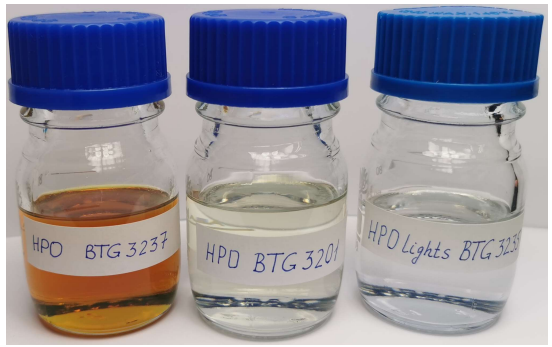

APO


Destillation residue 1


Destillation residue 2


UCOME residue


FPBO



HPO

Fuel characterisation

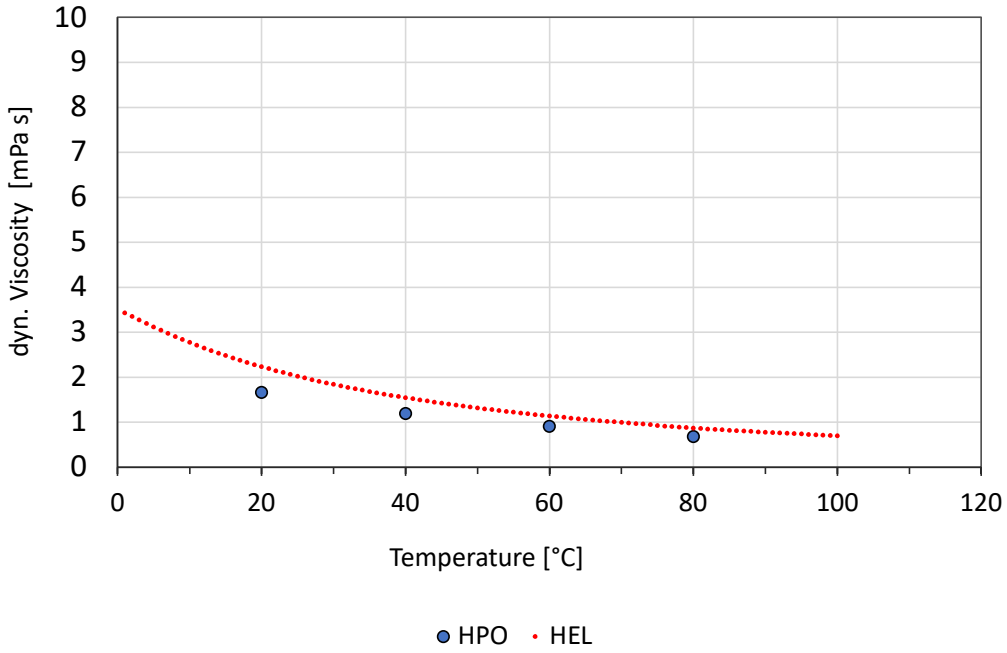
Science4Fuels
OWI
an der RWTH Aachen

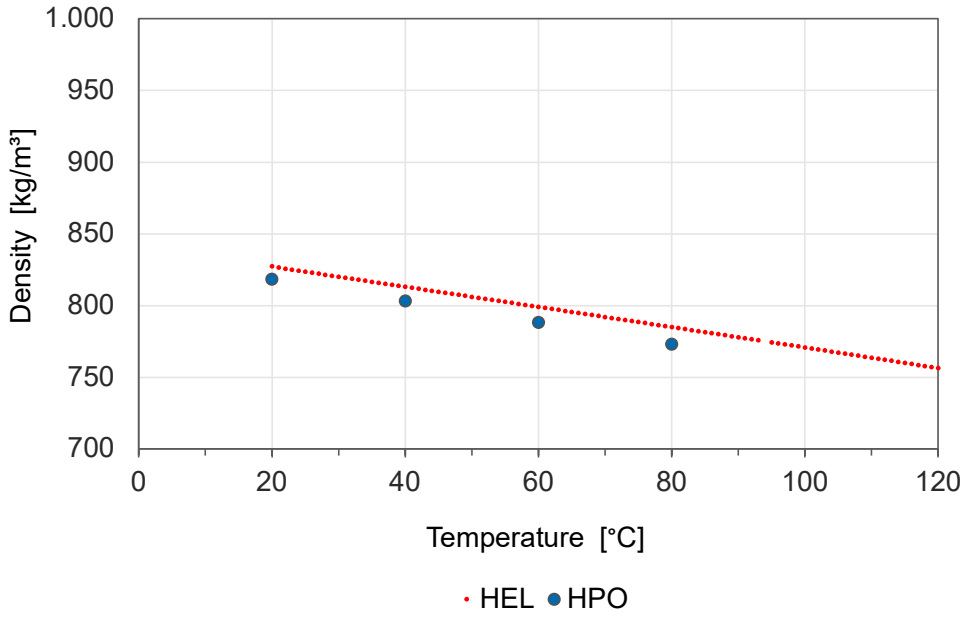
DIN 51603-1 Norm Values for domestic heating oil

Physical Properties	SI Units	Norm	min. Values	max. Values
Density [15°C]	$kg\ /\ m^3$	DIN EN ISO 12185	815	860
Flash Point (Pensky-Martens)	°C	DIN EN ISO 2719	>55	
Kin. Viscosity [20°C]	mm^2/s	DIN EN ISO 3104		6.00
evaporated volume fraction (up to 250°C)	%	DIN EN ISO 3405		< 65
evaporated volume fraction (up to 350°C)	%	DIN EN ISO 3405	85	
Cloud Point	°C	DIN EN ISO 23015		3
Cold Filter Plugging Point	°C	DIN EN 116		-12/-11/-10
Water Content	mg/kg	EIN EN ISO 12937		200

Fuel characterisation

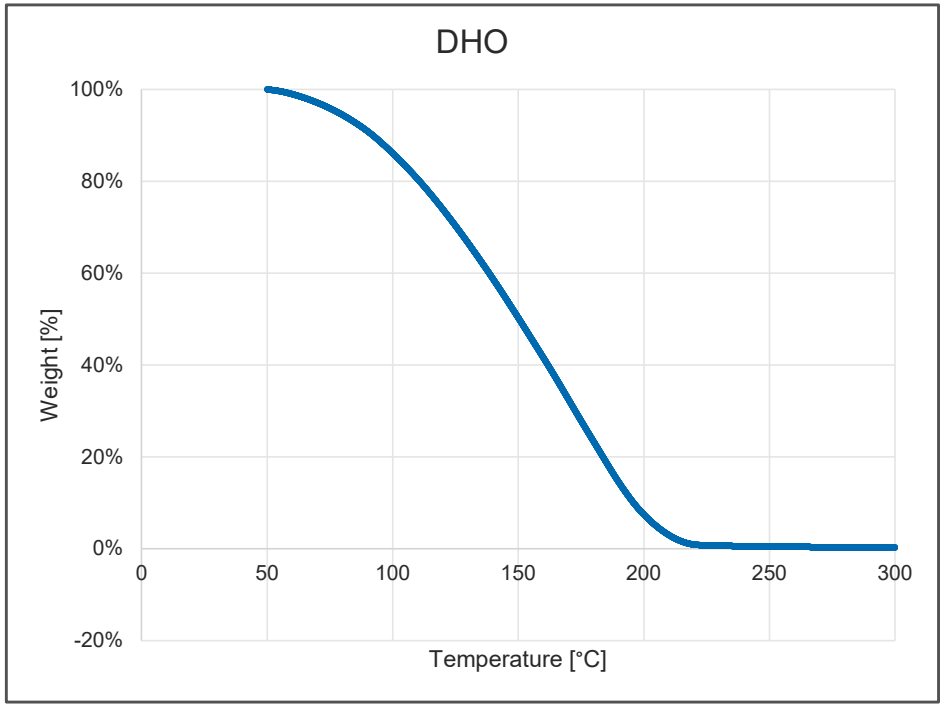
Hydrogenated pyrolysis bio oil

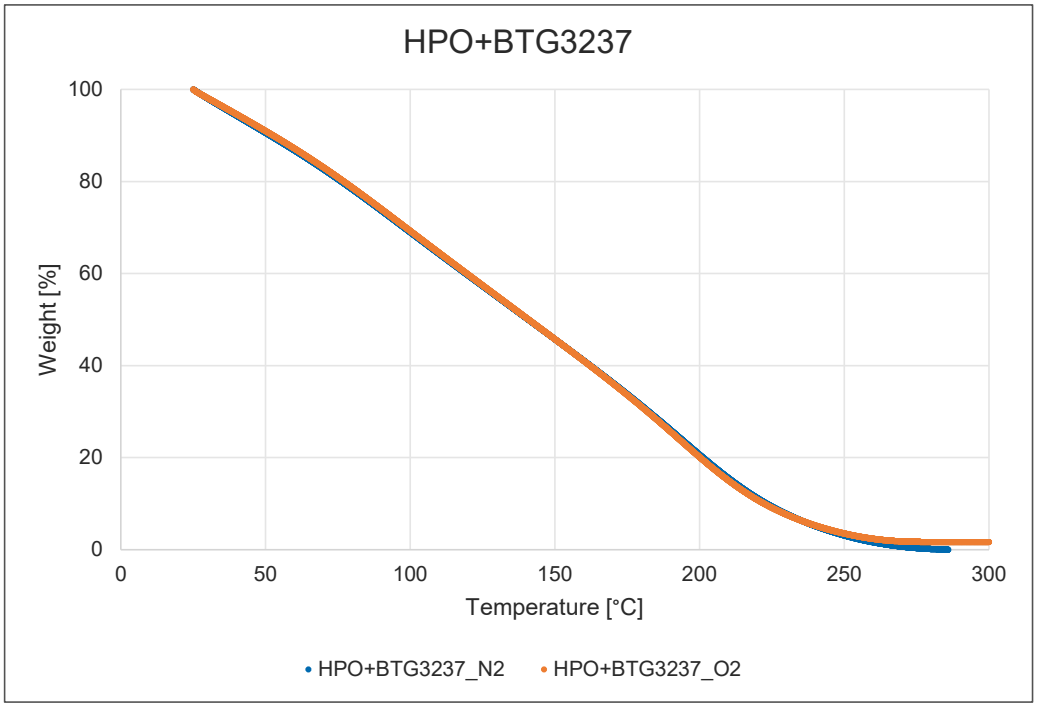




Fuel characterisation

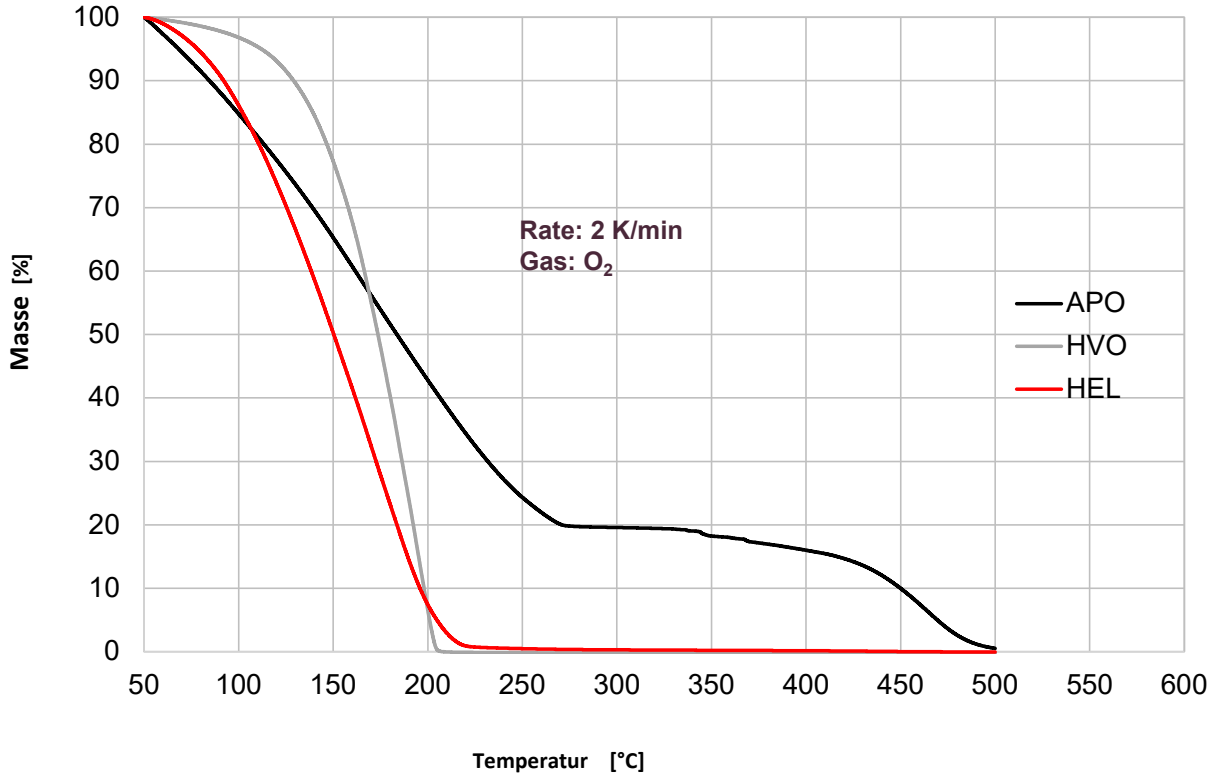
Thermogravimetric analysis





Fuel characterisation

Thermogravimetric analysis



Fuel characterisation

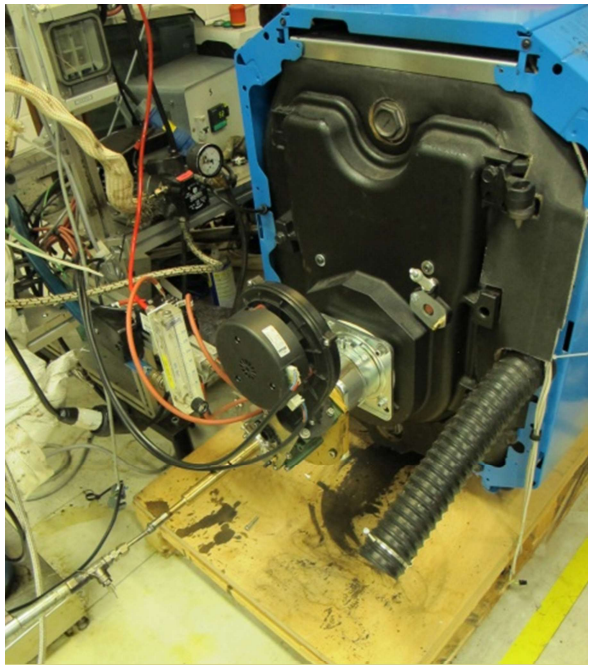
Single droplet evapourator

Destilation residue 1 (bottom), UCOME residue (top)

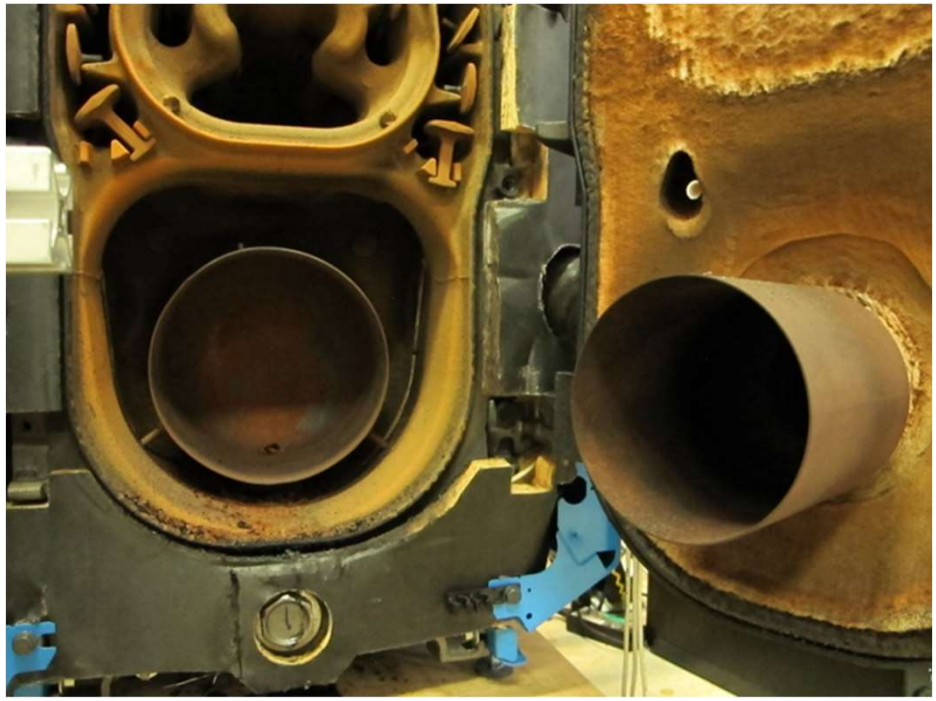
		
150°C	200°C	300°C
		
400°C	450°C	500°C

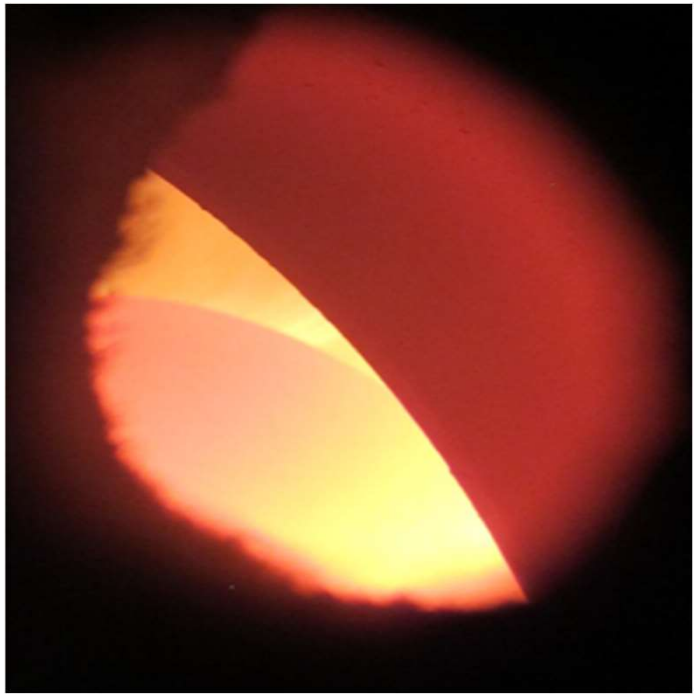
R2H FPBO burner application to a boiler

- Bosch GB125-20
- 20kW$_{th}$ power output
- Cast iron heat exchanger
- Condensing boiler



R2H FPBO burner application to a boiler

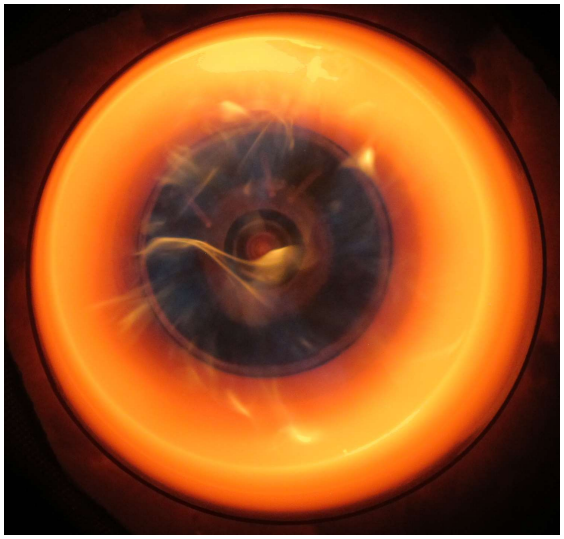




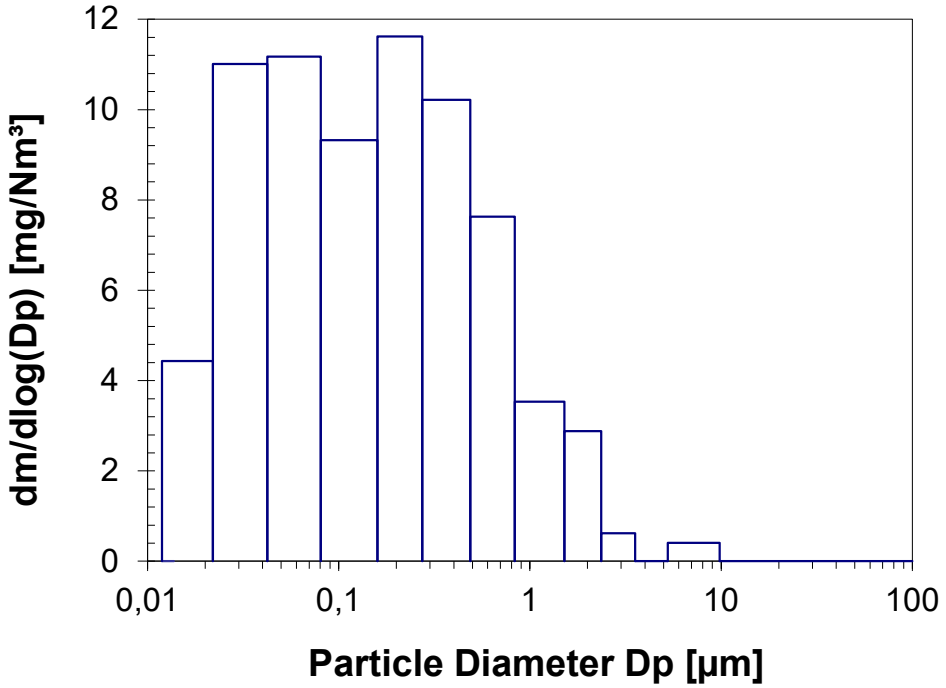
Emissions

FPBO

Power	O_2	CO	NOx
kW	Vol-%	ppm	ppm
15,5	2,9	7	480



PM_1: 17,25 mg/m^3_N
$PM_{2,5}$: 18,73 mg/ m^3_N
PM_{10}: 18,95 mg/ m^3_N
PM_Σ: 18,95 mg/ m^3_N



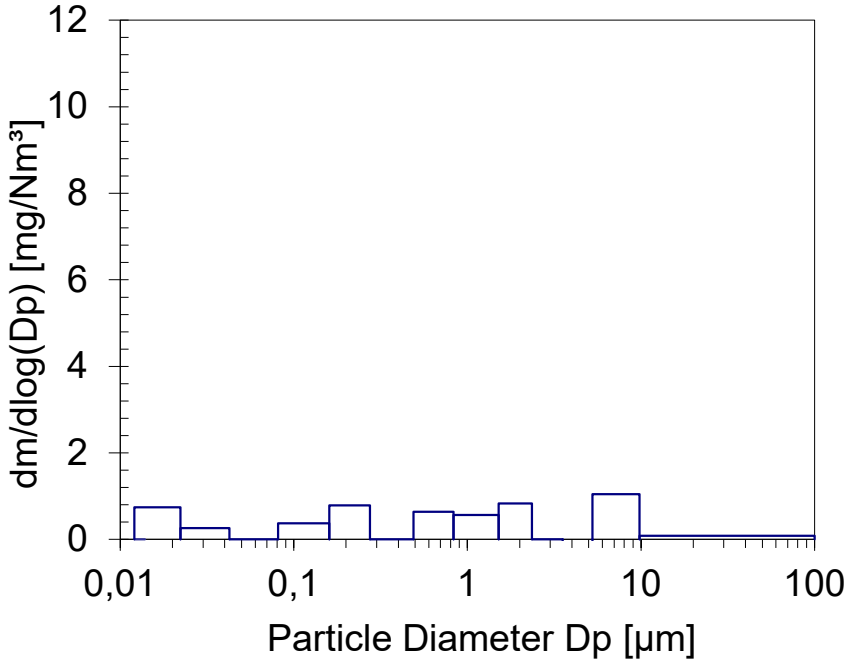
Stage II Federal Immission Control Act (BimschV):
Single-room furnaces 40 mg/ m^3_N @15%$O_{2\ dry}$

SmartCHP Emissions

Domestic heating oil (DHO)

Power	O_2	CO	NOx
kW	Vol-%	ppm	ppm
16	3,3	8	69

PM_1: 0,858 mg/m^3_N
$PM_{2,5}$: 1,02 mg/ m^3_N
PM_{10}: 1,12 mg/ m^3_N
PM_S: 1,38 mg/ m^3_N



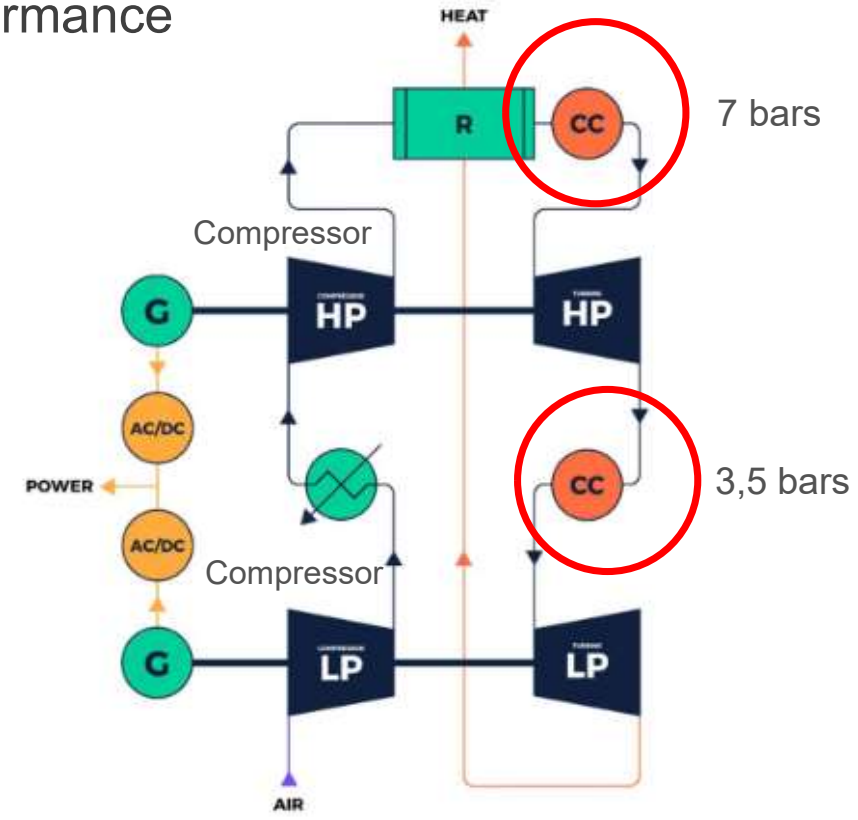
Challenges

Fuel feeding and dosing:

- Extreme pump wear
- Tendency to varnish fuel on contact with air
- Formation of sticky wall films

Fit4Micro

- Experimental validation of the combustor performance
- Mild combustion mode
- HPO fueled
- Pressure up to 3,5 bar and 7 bar
- Low Emissions



Spray Angles Detection

SLM50

SLM60

SLM70

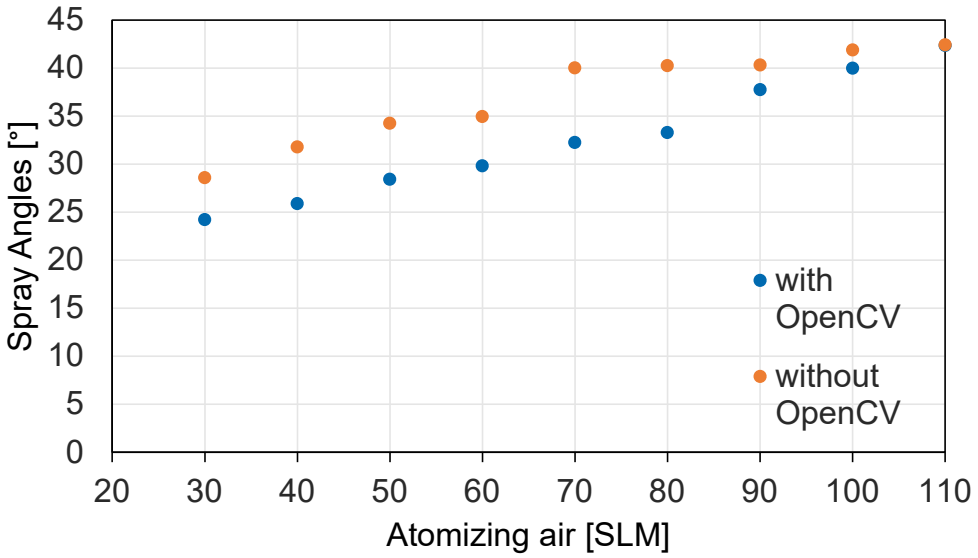
SLM80

SLM90

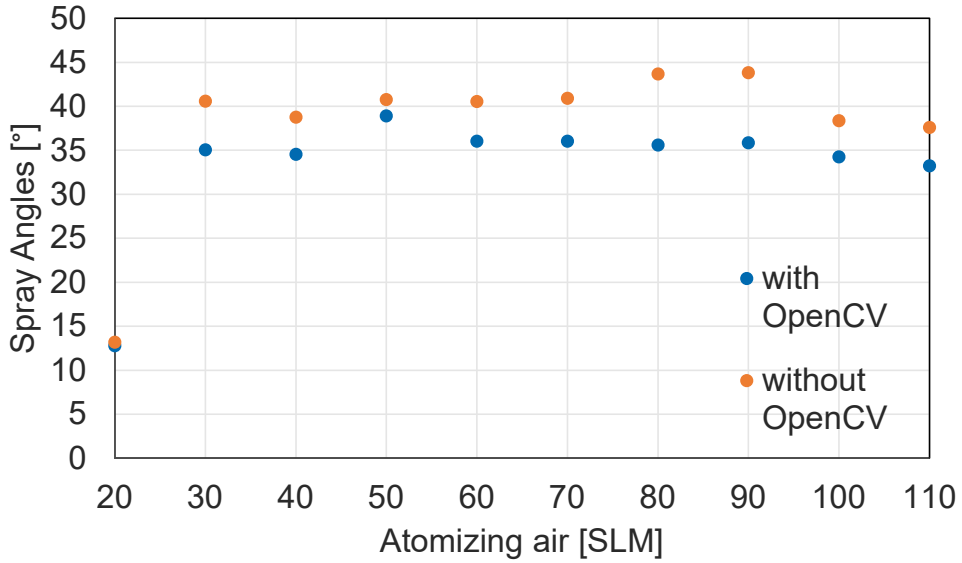
SLM 50 – 90; Mass flow 5kg/h; Spray Head “Mitis” (+)

Spray Angle Detection

Mitis , Mass flow 3kg/h

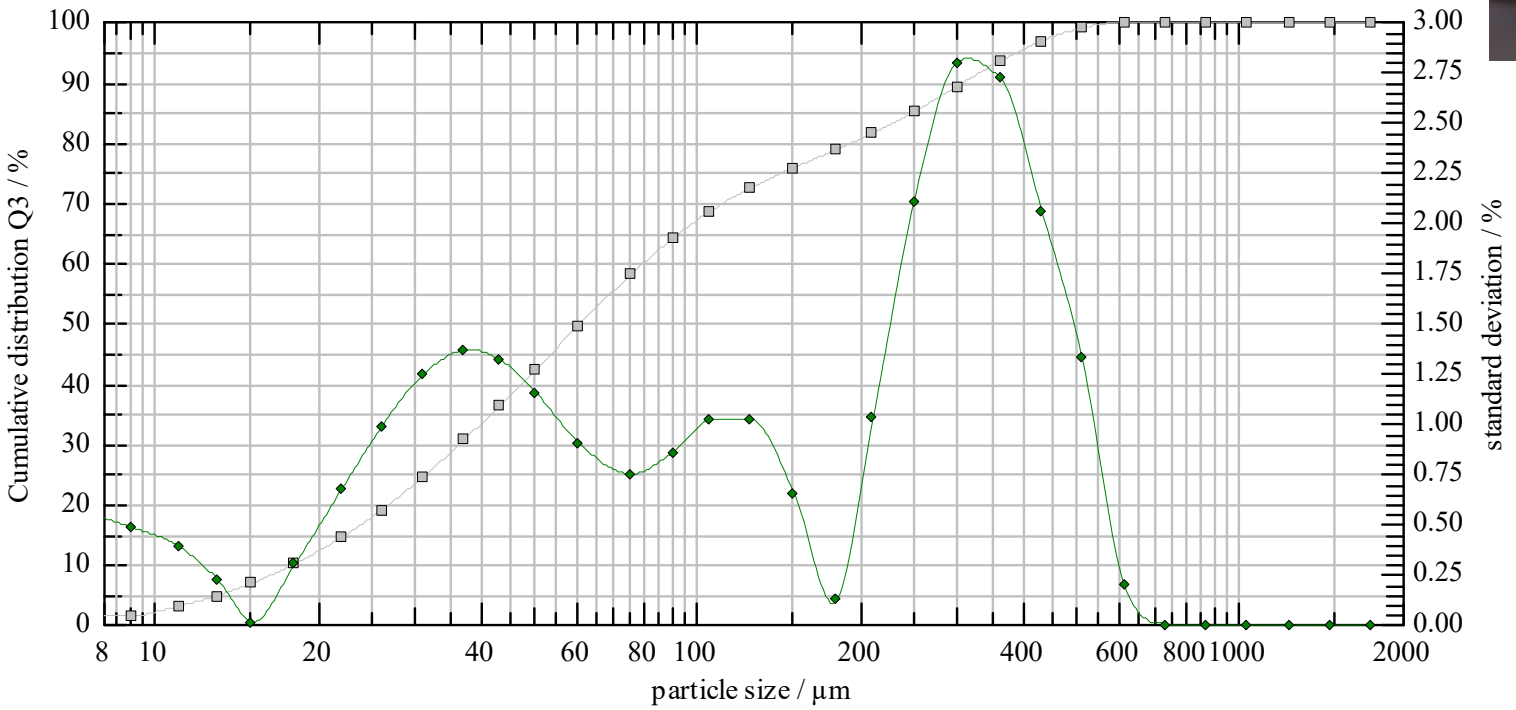


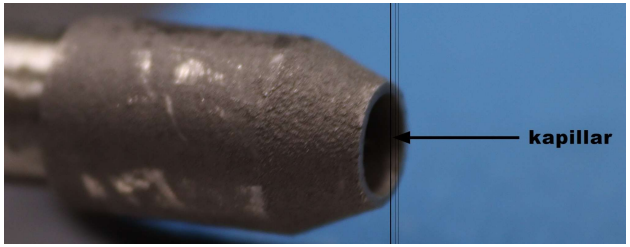
Mitis , Mass flow 5kg/h



Particle Size Analysis

Two substance nozzle, MITIS 1 st design



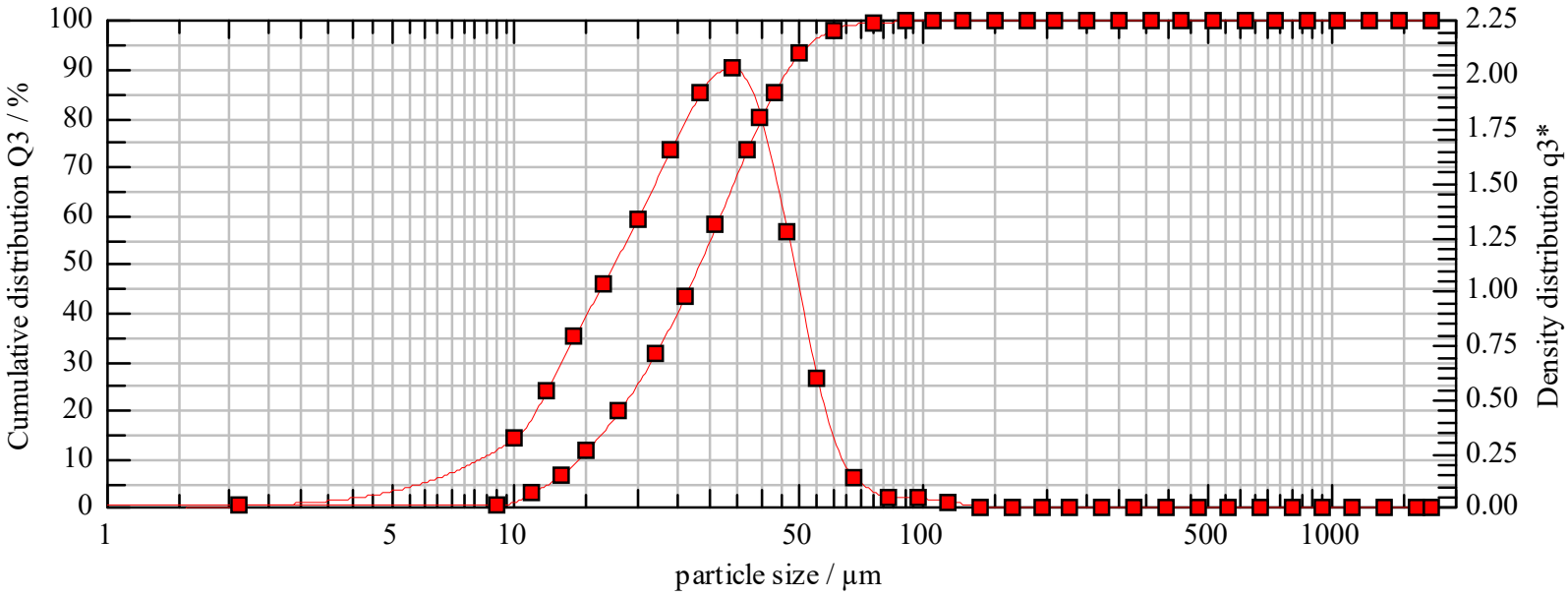


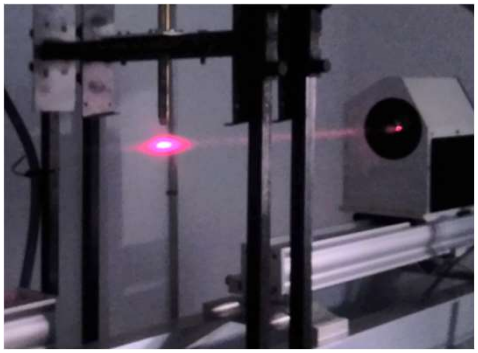
Fuel: 0,85 g/s
Atom. Air: 110 slm

x_{10}	= 18.03 +/- 0.28 µm
x_{50}	= 60.97 +/- 1.54 µm
x_{90}	= 313.66 +/- 36.55 µm
SMD	= 39.80 µm

Particle Size Analysis

Two substance nozzle, MITIS 2 nd design





Fuel: 4,2 kg/h
Atom. Air: 6,5 slm

x_{10}= 14.39 µm
x_{50}= 28.35 µm
x_{90}= 47.26 µm

SMD= 24.59 µm

Summary and Outlook

- The combustion properties of HPO are close to those of heating oil
- No tendency to varnish in contact with air
- No problems with fuel feeding so far
- Minimisation the of degree of hydration
- Tests with 2 nd design MITIS nozzle
- Tests under pressure

Thanks for your Attention!

Kontaktdaten:

Dirk Möntmann

OWI – Science for Fuels gGmbH
Kaiserstraße 100
52134 Herzogenrath

Tel.: +49 2407 9518 119
E-Mail: d.moentmann@owi-aachen.de