MGT Fuel Flexibility

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Agenda

- State of the art
- On-going research activities (@ DLR) regarding fuel / fuel flexibility
- Collaboration and way forward

State of the art
MGT manufacturer US

- **Capstone**
  - Natural Gas: LHV 32.5 - 50.2 MJ/m^3
  - LPG (Propane)
  - Biogas
    - LHV > 13,8 MJ/m^3 (landfill gas)
    - CH4 > 24 Vol.-%
  - Diesel / Kerosene

- **FlexEnergy**
  - Gaseous fuels: WI > 12.1 MJ/m^3
  - $H_2S \leq 6500$ ppm

State of the art
MGT manufacturer EU

- **Ansaldo (AE-T100)**
  - Natural Gas: LHV: 38 - 50 MJ/kg
  - Biogas
    - LHV > 16 MJ/kg
    - CH4 > 40 Vol.-%
    - H_2S ≤ 1500 ppm

- **MTT**
  - Natural Gas (H, E, L): LHV: 32 - 45 MJ/kg
  - Future: LPG, Heating oil, Biogas, H_2

State of the art
Gaseous fuels

- **Natural gas** (also sour gas; different NG qualities (high C_{2+} content))
- **Biogas** (biomass, sewage): CH_4, CO_2 (40 - 75 Vol.-% CH_4)
- **Landfill gas**: CH_4, CO_2 (25 – 60 Vol.-% CH_4)
- **Manufactured gases** (Gasification / pyrolysis process)
  - **City gas**, **wood gas**: H_2, CO, CH_4, CO_2, N_2; LHV = 3 - 5 MJ/kg
- **Hydrogen** / hydrogen mixtures (‚power to gas')
- **Industrial waste gas** (flare gas, process off-gas (petroleum refineries, chemical plants, natural gas processing plants, …)): CH_4, C_{2+} (C_2H_6, C_3H_8, C_4H_{10}, C_5H_{12})
- Blast-furnace gas: N2, CO, CO_2, H_2, LHV = 3,3 - 4 MJ/m^3

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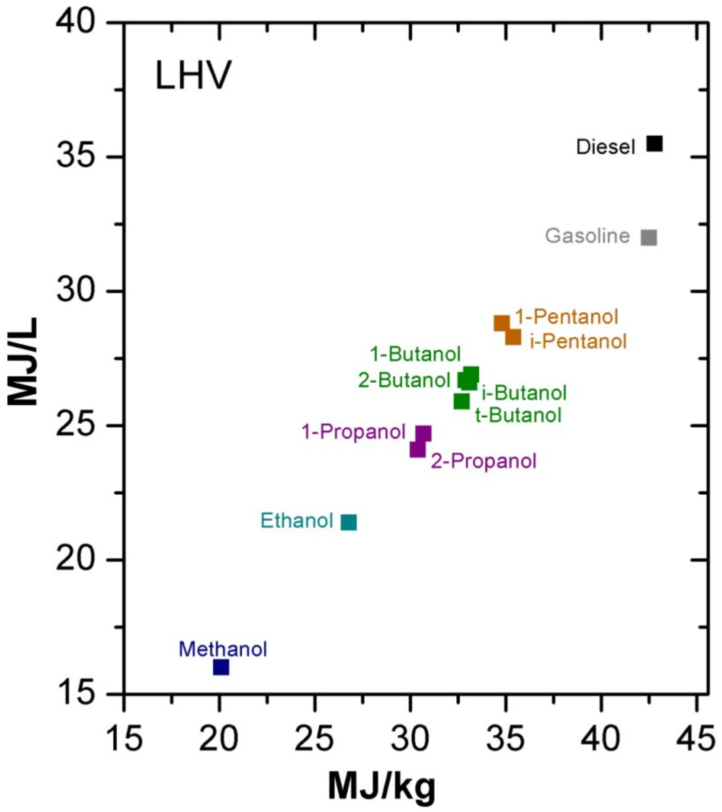
State of the art
Liquid fuels

- **Heating oil**
- **LPG / NGL**
- **Diesel**
- **Kerosene**
- **Liquid hydrocarbons** (‚power to liquid‘: electrolysis+gasification+Fischer-Tropsch, e.g. Nonan C9 (n-alkane))
- **Acohols**: Methanol, Ethanol, Butanol, Pentanol
- **VOCs** (Volatile Organic Compounds; industrial emissions): Methanol, Ethyl acetate, Toluene
- **Pyrolysis oil**
- Glycerin

State of the art
Liquid fuels

- Energy density



Fuel	Lower heating value (LHV)§	
	(MJ/l)	(MJ/kg)
Gasoline	30-33	41-44
Diesel	35.5*	43
Methanol	16*	20
Ethanol	21.4	26.8
1-Propanol	24.7	30.7
2-Propanol	24.1	30.4
1-Butanol	26.9	33.2
2-Butanol	26.7	32.9
i-Butanol	26.6	33.1
t-Butanol	25.9	32.7
1-Pentanol	28.5	34.8
i-Pentanol	28.3	35.4

§Yanowitz et al. Technical Report, NREL/TP-5400-50791, August 2010
*Lassi, U., SusEn Annual Seminar, 6-7 Oct, Helsinki, 2009

State of the art
MGT vs. piston engines - advantages

- Less prone to **autoignition characteristics / detonation tendency** (e.g. addition of hydrogen or C_{2+})
- Easier usage of **low LHV fuels** (especially containing hydrogen) → derating of piston engines (comparable electric efficiencies), higher pretreatment of fuels
- **Fuel flexibility** (with same combustor design)
  - Biogas / Natural Gas / mixtures of biogas and natural gas in micro grids (injection of NG to compensate peak demand / downtime of fermantation plant, etc.)
  - Natural Gas / Hydrogen / mixtures of hydrogen and natural gas (to compensate peak demand)

State of the art
MGT vs. piston engines - advantages cont.

- **Duel fuel capability** (with same combustor design)
  - e.g. Natural Gas + heating oil / Diesel
- Lower requirements of **fuel quality** & lower maintenance effort
  - Contaminants
  - Varying fuel quality (varying composition)

→ MGT application in respect to fuel flexibility could be especially successful in niche markets

→ Requirements: combustion systems ensuring stable, efficient combustion with lowest emissions and low pressure loss

Research activities @ DLR-VT

- Gas turbine combustion research for small and large GTs
- Development and test of micro gas turbine power plant concepts

Research activities @ DLR-VT
MGT combustion research

- **Turbec T100**

  (FLOX®-based combustor with swirl stabilzed pilot stage)

  - Natural Gas, Natural gas qualities
  - Wood gas
  - VOC / NG

- **MTT EnerTwin**

  (single stage FLOX®-based combustor)

  - Natural Gas
  - SOFC-Off gas / Natural Gas / Biogas (one combustor design)
  - Biogas / mixtures of NG and Biogas (one combustor design)
  - NG + exhaust gas recirculation (up to 80% of EGR / 10% remaining O_2)

Research activities @ DLR-VT
MGT combustion research (cont.)

- **Garrett GT36-28**

  (combustion system based on the FLOX®-concept)

  - Kerosene

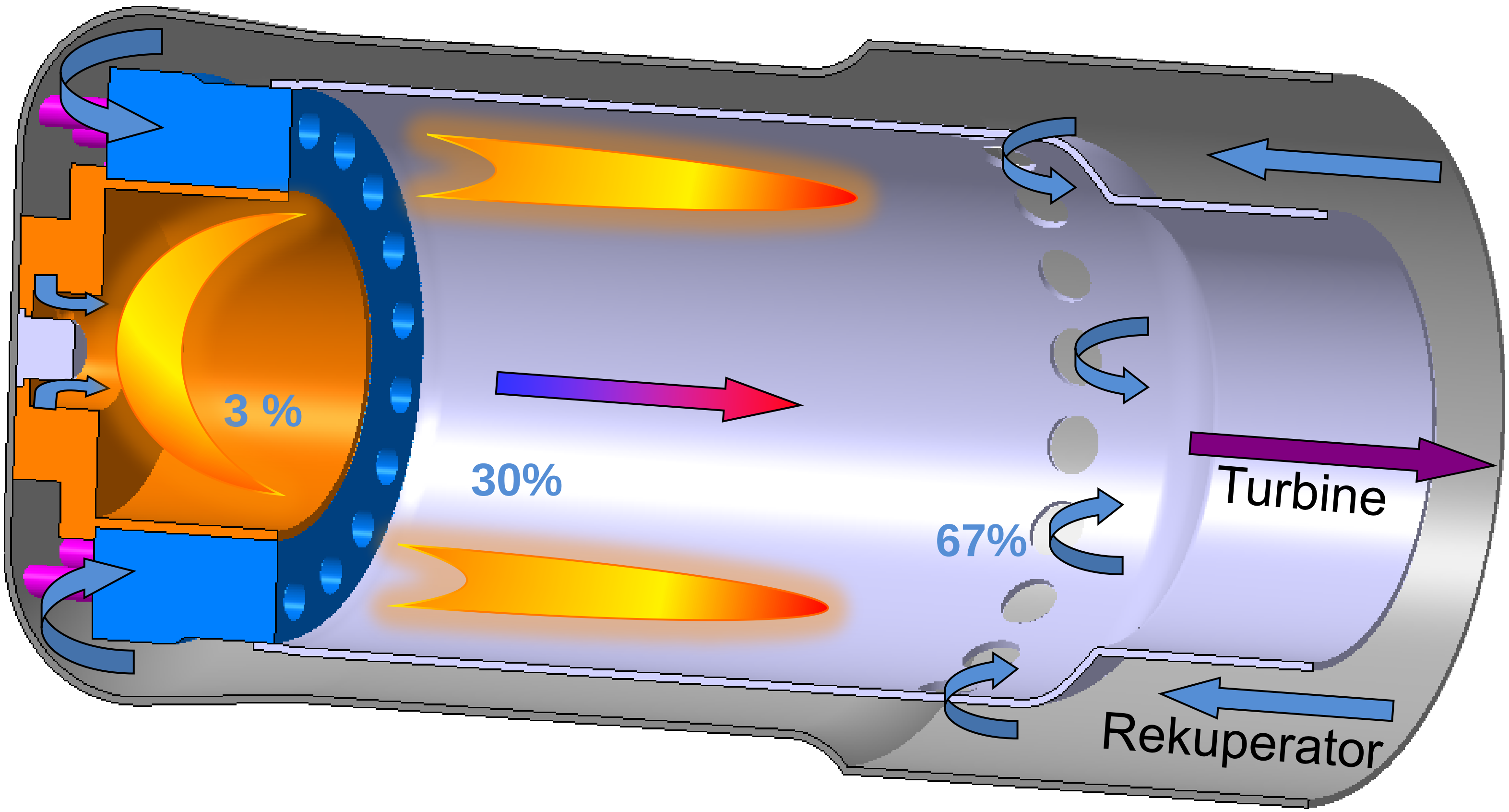
- **Engine independent**

  (combustion systems based on the FLOX®-concept)

  - Diesel
  - H_2 / mixtures of H_2 and NG
  - Pyrolysis oil

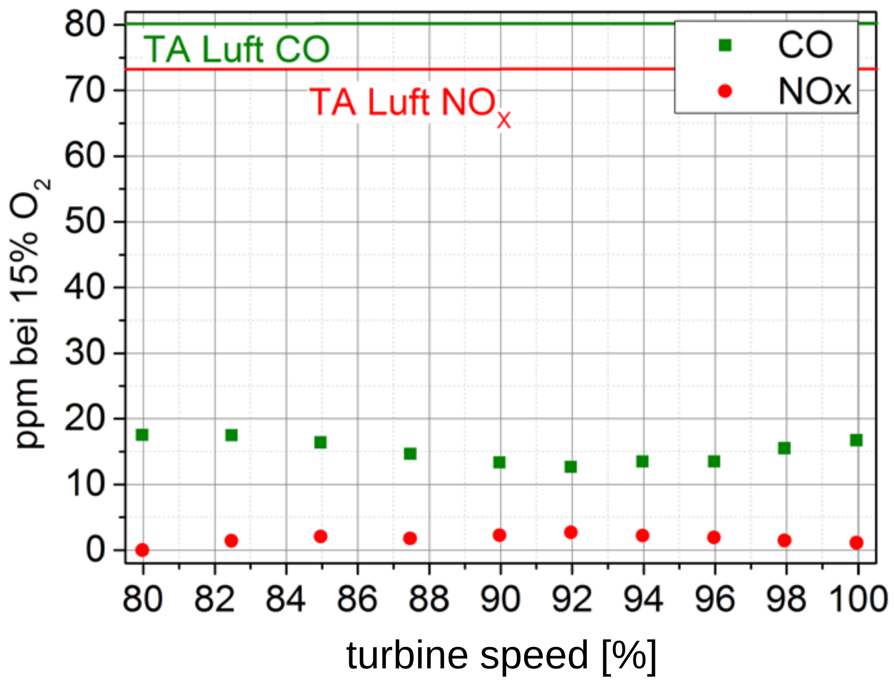
Research activities @ DLR-VT
MGT combustion research

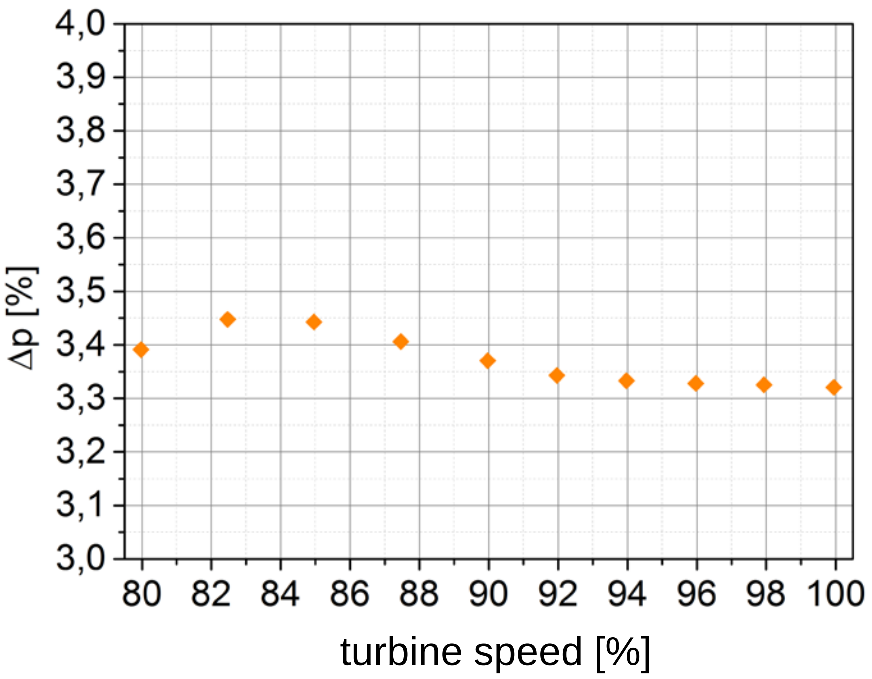
- FLOX® combustion system Turbec T100



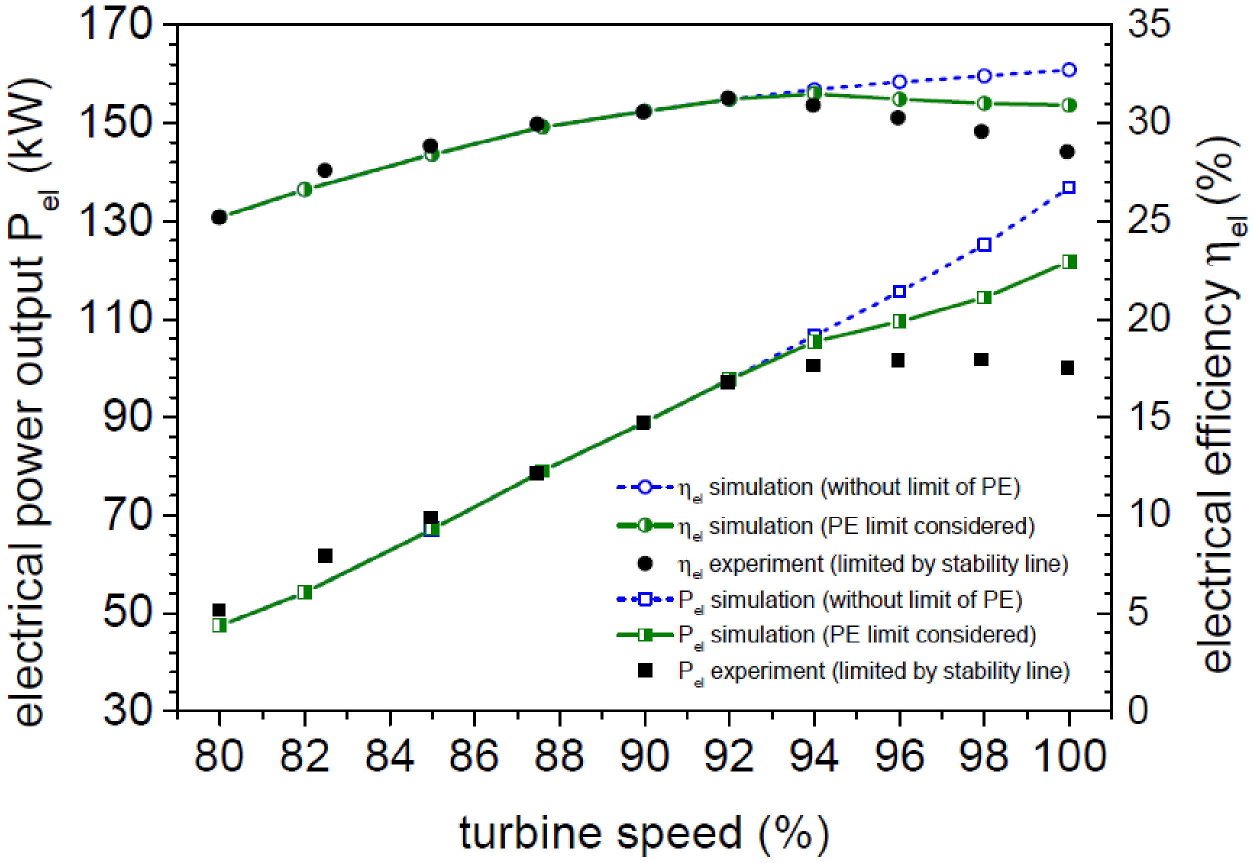
Research activities @ DLR-VT
Wood gas

	H_2 [%]	CO [%]	CH_4 [%]	CO_2 [%]	N_2 [%]	LHV [MJ/kg]
NG	0	0	93,4	0,9	1,8	48,6
Wood gas	18	22	2,25	12	45,75	5,0





Research activities @ DLR-VT
Wood gas



Zornek, T., Monz, T., Aigner, M.: Performance analysis of the micro gas turbine Turbec T100 with a new FLOX-combustion system for low calorific fuels, Applied Energy 159 (2015), pp. 276-284

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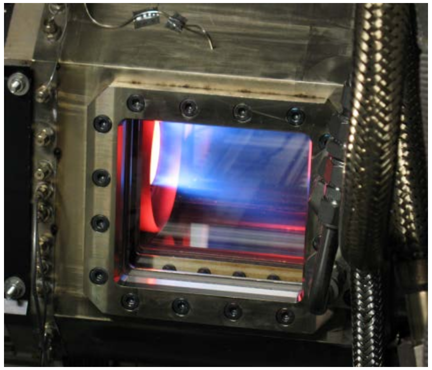
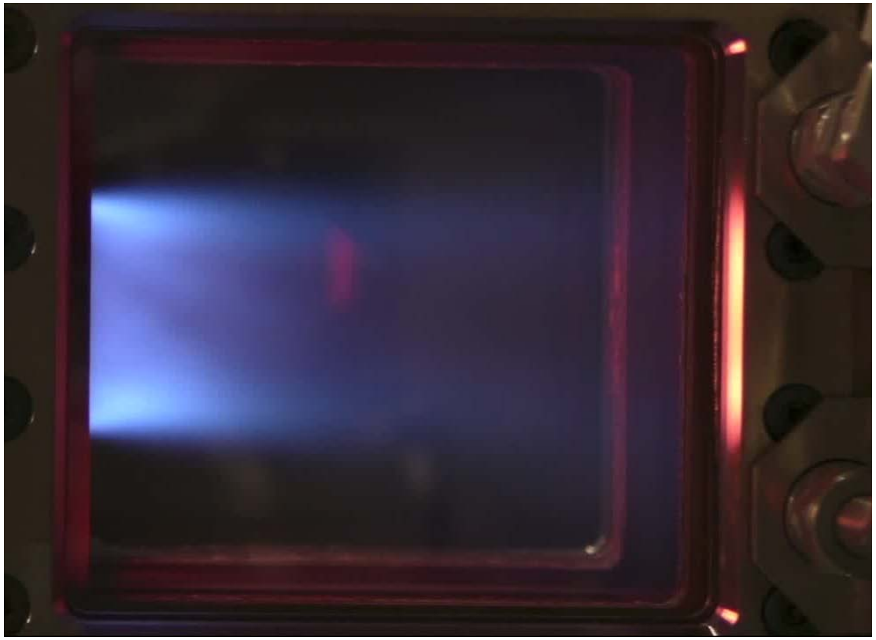
Research activities @ DLR-VT
Wood gas

- Engine test with optical accessible combustion chamber

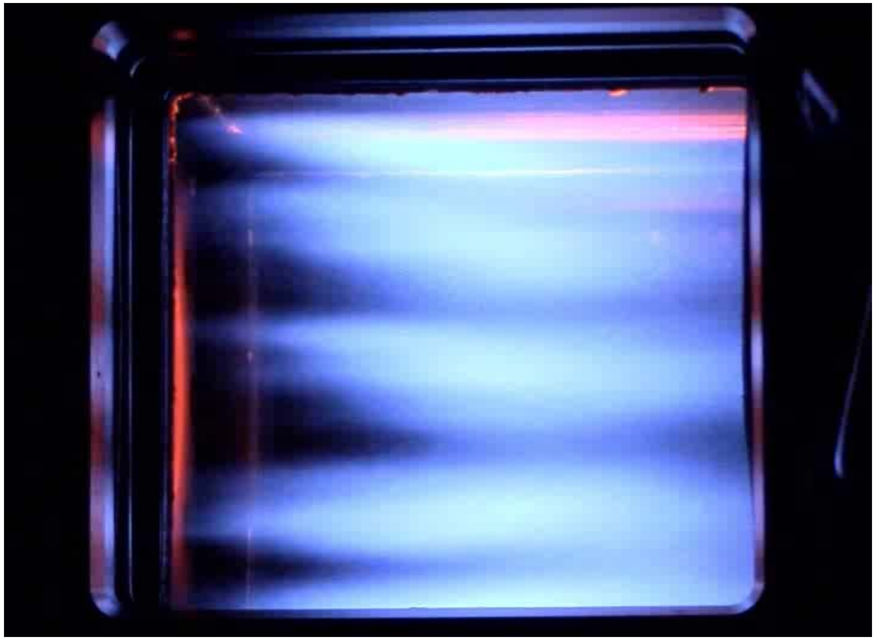


Turbec T100 combustor NG

FLOX® combustor (wood gas)



90 % turbine speed



90 % turbine speed

Research activities @ DLR-VT
Wood gas – variation of composition

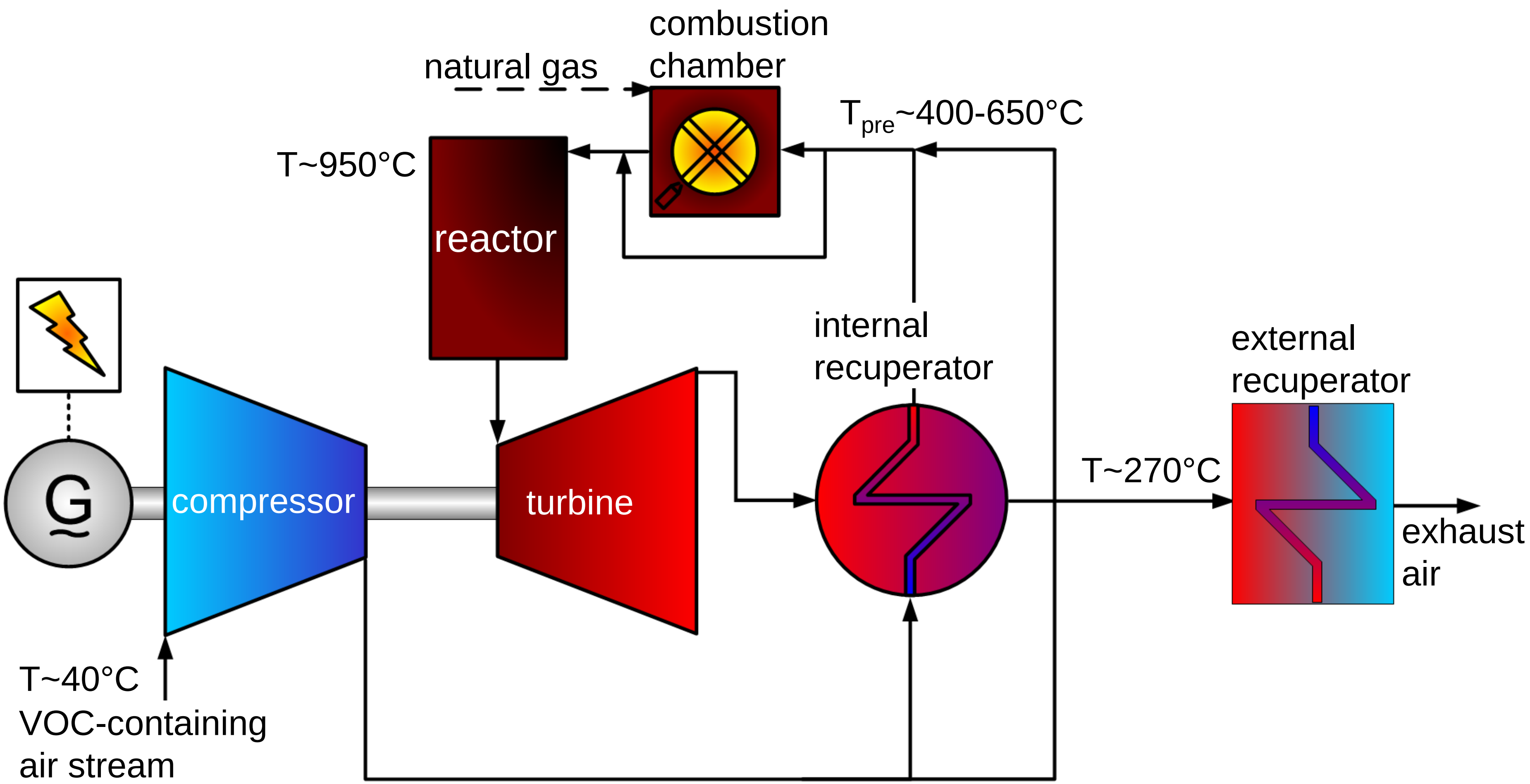
- OH* chemiluminescence (optical accessible combustion chamber)

30% H_2, 10% CO, 1% NG, 12% CO_2 47% N_2

15% H_2, 17,6% CO, 5% NG, 12% CO_2, 50,4% N_2

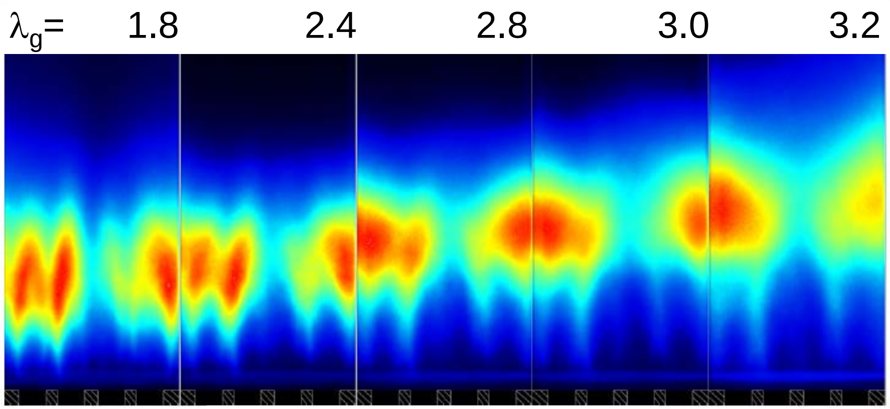
0% H_2, 19% CO, 11% NG, 12% CO_2, 58% N_2

Research activities @ DLR-VT
Thermal incineration of VOCs

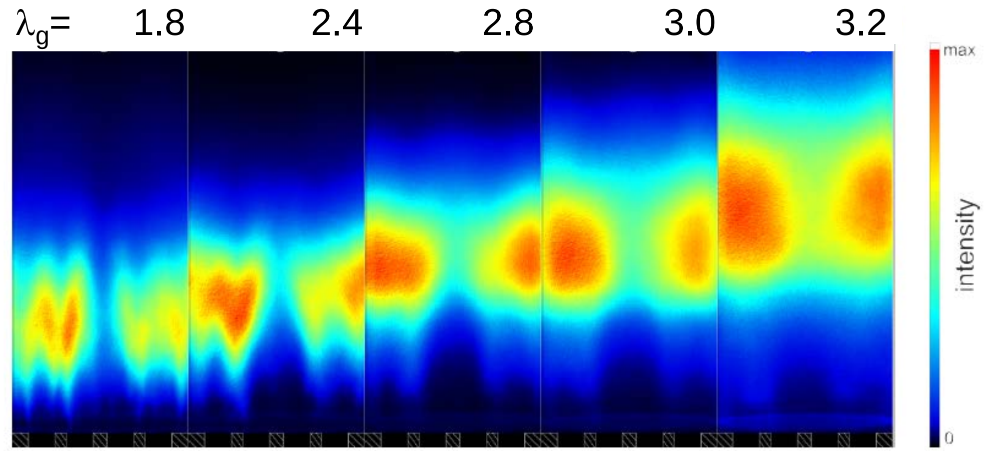


Research activities @ DLR-VT
Thermal incineration of VOCs

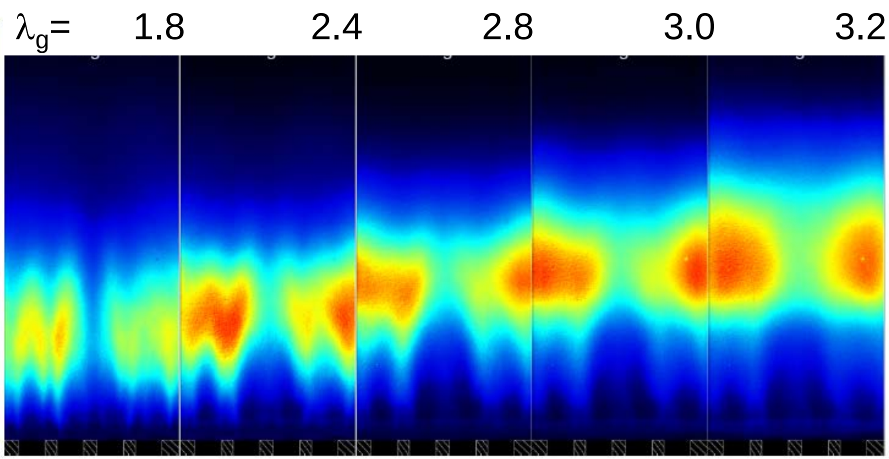
T_{pre}=650°C: OH* chemiluminescence



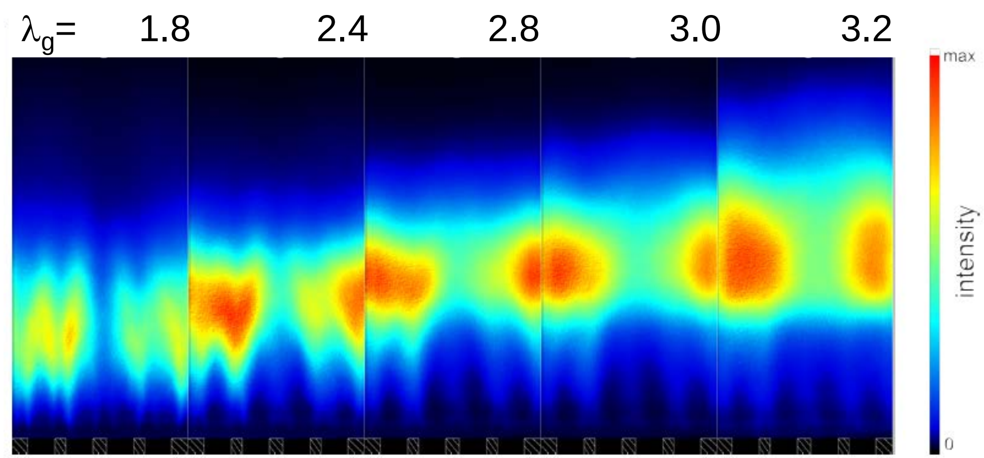
(a) reference / natural gas



(b) methanol at 0.25 MJ/Nm³



(c) ethyl acetate at 0.25 MJ/Nm³



(d) toluene at 0.25 MJ/Nm³

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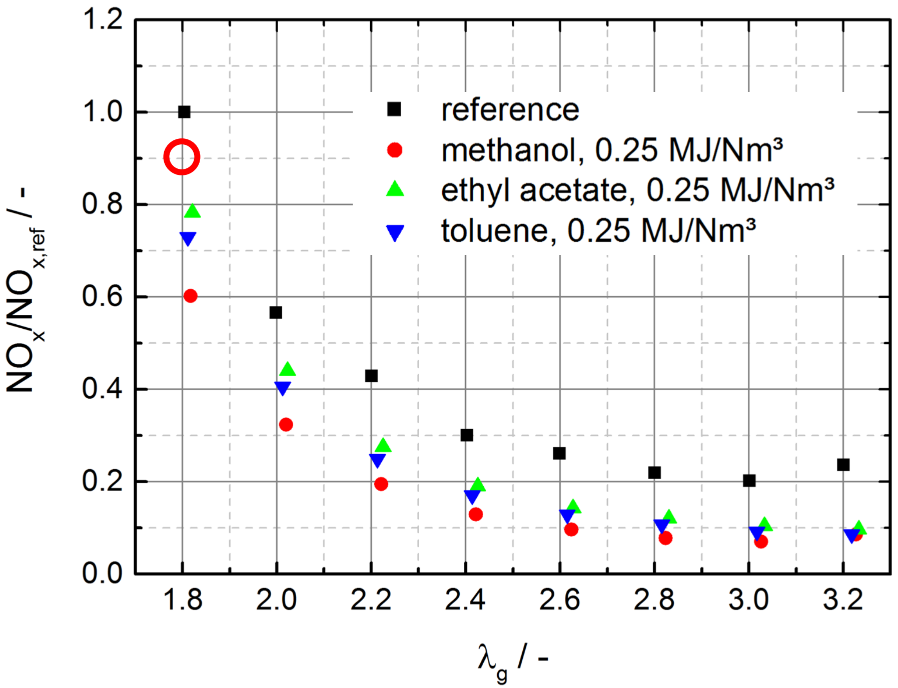
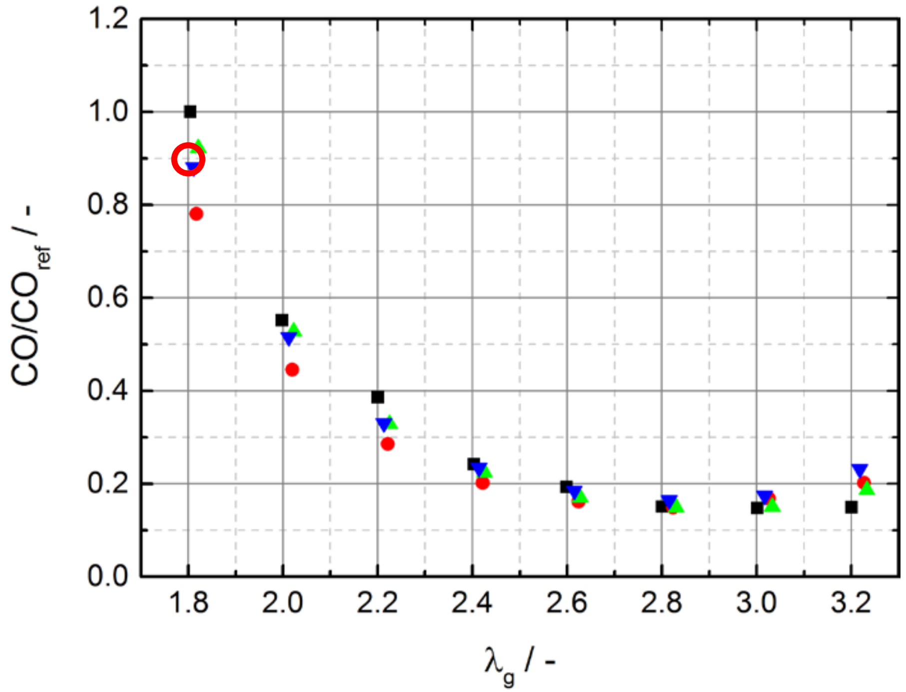
Research activities @ DLR-VT

Thermal incineration of VOCs

T_{pre}=650°C: Emissions





ref: emission value of the reference case at λ_g=1.8

A. Schwärzle, T. Monz, M. Aigner
Thermal Incineration of VOCs in a Jet-Stabilized Micro Gas Turbine Combustor
Proc. ASME Turbo Expo 2015, Power for Land, Sea and Air, June 15-19, 2015, Montreal, Canada, GT2015-43139

Research activities @ DLR-VT

Combined SOFC-Off Gas / natural gas combustor

- FLOX®-based combustor with 12 nozzles
- SOFC-Off gas production with „hot steam generator“ (H_2/O_2 flame)

	H_2 [%]	CO [%]	H_2O [%]	CO_2 [%]	NG [%]	P_{fuel} [kW]	T_{fuel} [°C]	T_{air} [°C]	T_{adi} [°C]	LHV [MJ/kg]
Off-gas	1,0	5,3	42,7	51	-	3,82	770	710	1211	**1,96**
NG (700°C)	-	-	-	-	100	6,22	15	700	1688	**47,85**
NG (100°C)	-	-	-	-	100	6,22	15	100	1418	**47,85**

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Research activities @ DLR-VT
Combined SOFC-Off Gas / natural gas combustor

- OH* chemiluminescence

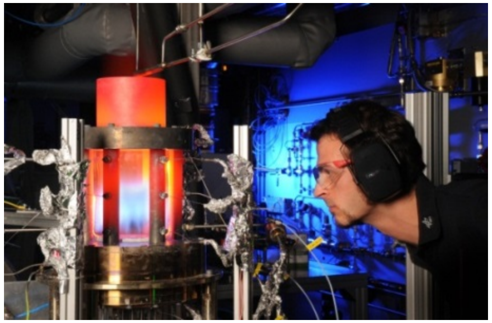
SOFC-Abgas:
T_v=710 °C, λ=2.6

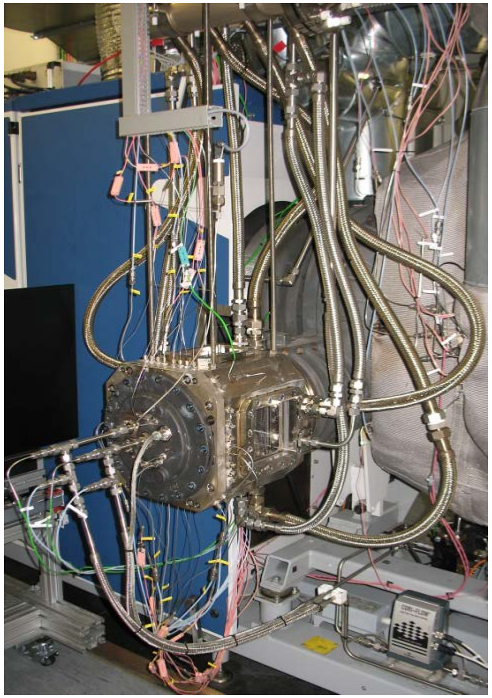
NG:
T_v=700 °C, λ=2

NG:
T_v=100 °C, λ=1.8

Collaboration and way forward

- DLR-VT offers its expertise in developing combustion systems for all kind of MGTs and fuels
  - Development of chemical reaction mechanisms / schemes for „new" fuels for CFD application (also characterisation of fuels: flame speed, ignition delay time)
  - Numerical design using in-house CFD codes with detailed chemistry
  - Atmospheric and high pressure combustor test rigs for all liquid and gaseous fuels
  - MGT test rigs modified and instrumented for research purpose





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