14th EUROPEAN CONFERENCE
ON INDUSTRIAL FURNACES AND BOILERS
2 - 5 April 2024 - Algarve, Portugal
INFUB

CFD Modelling of an 850 kW Injection Furnace to Investigate NOx Emissions

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Aprll 4th, 2024

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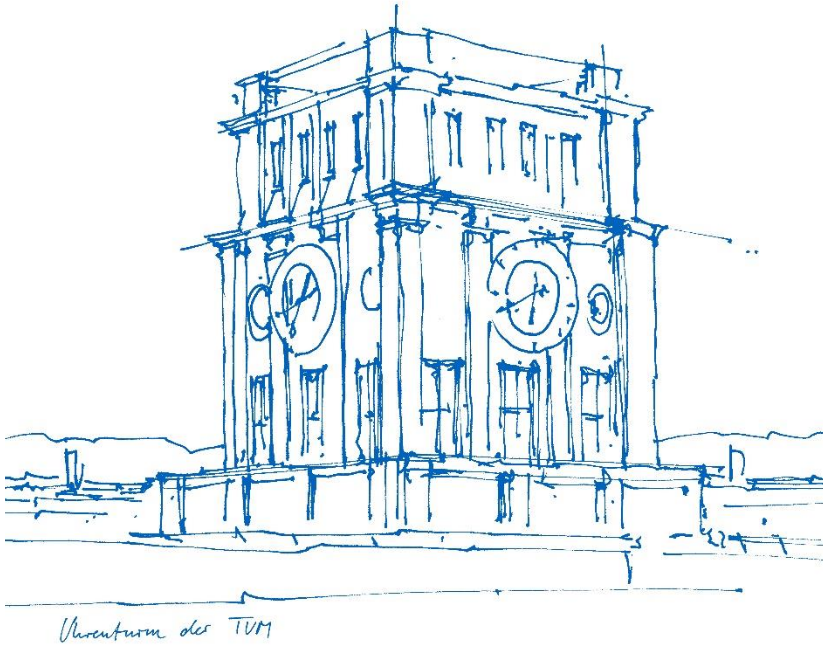


Agenda

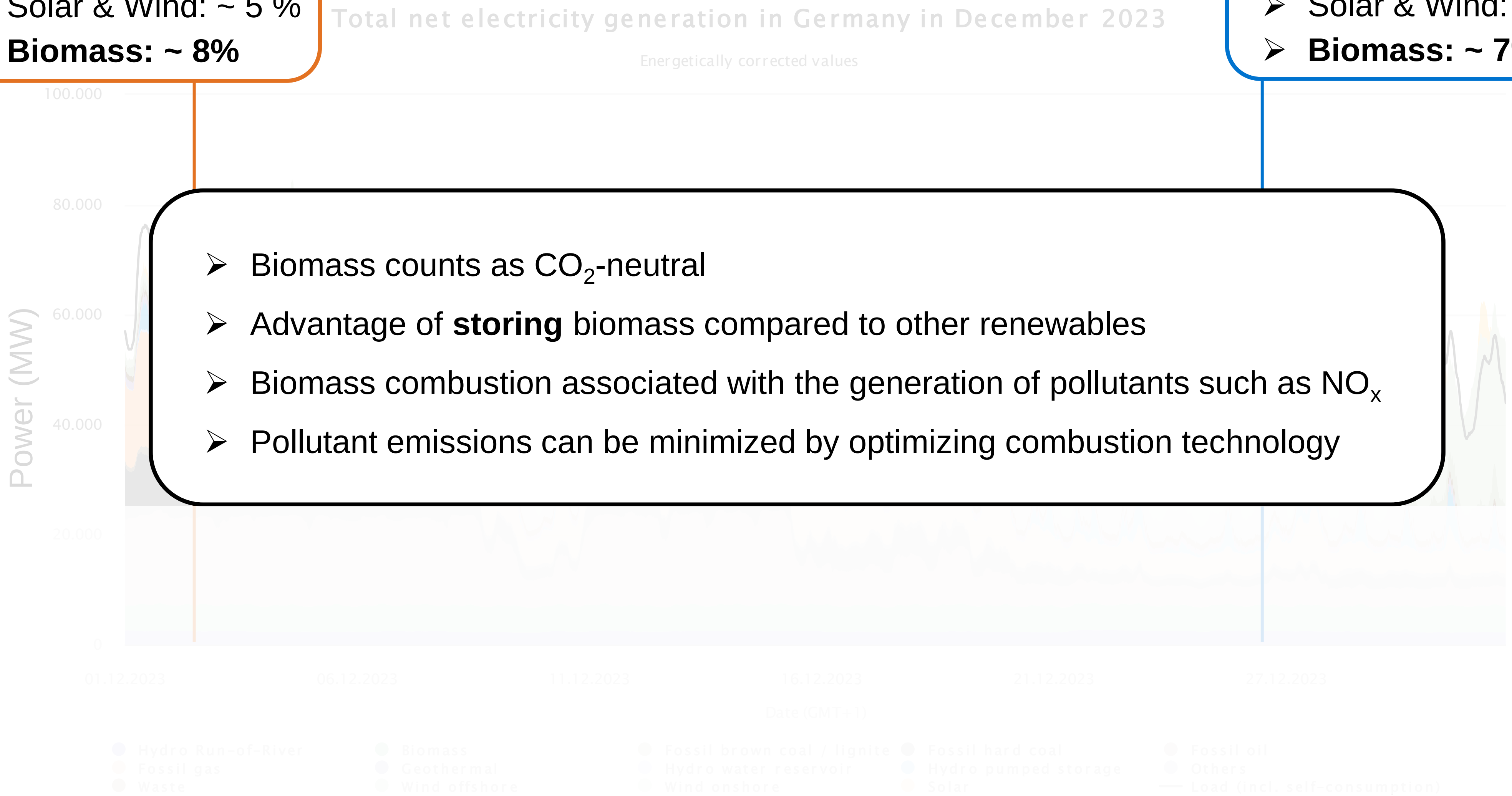
- Motivation
- Project OptiNOx
- CFD-Model
- Scale-Up and Results for the 850 kW Furnace
- Summary and Outlook

02.12.2023:

- Fossil Fuels: ~ 76 %
- Solar & Wind: ~ 5 %
- **Biomass: ~ 8%**

26.12.2023:

- Fossil Fuels: ~ 14 %
- Solar & Wind: ~ 64 %
- **Biomass: ~ 7%**



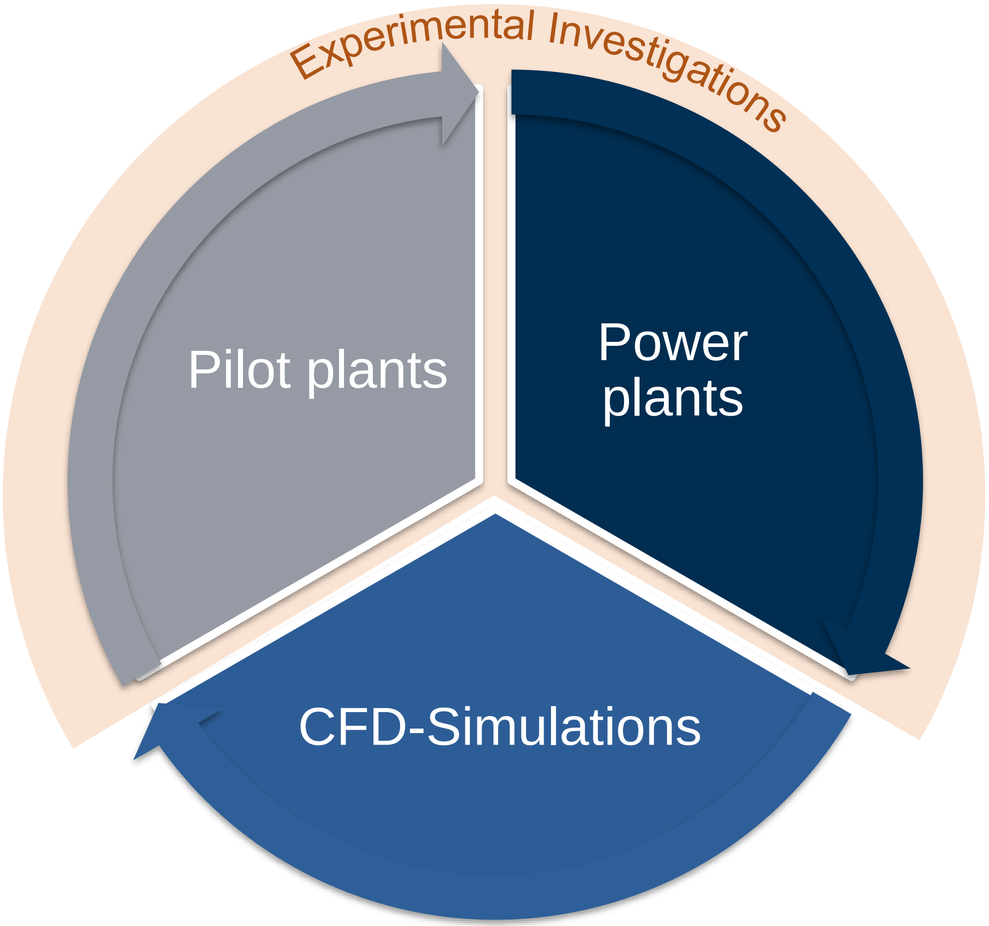
- Biomass counts as CO_2-neutral
- Advantage of **storing** biomass compared to other renewables
- Biomass combustion associated with the generation of pollutants such as NO_x
- Pollutant emissions can be minimized by optimizing combustion technology

Sources: energy-charts.info, online, accessed 02.04.2024

OptiNOx (Optimization of biomass furnaces with the aim of reducing NOx emissions)

Preliminary studies

➢ characterization of the fuel

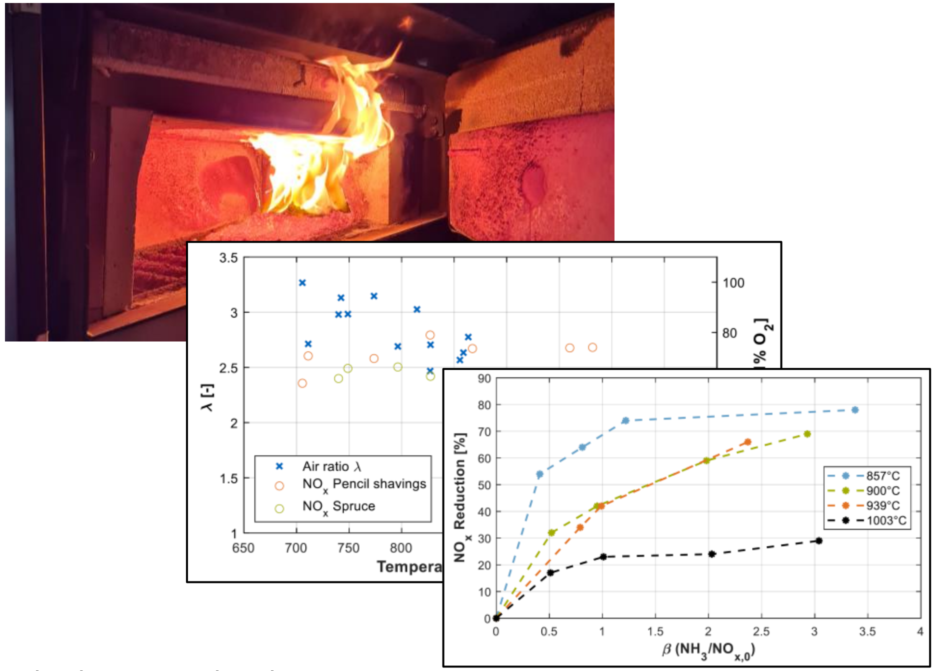


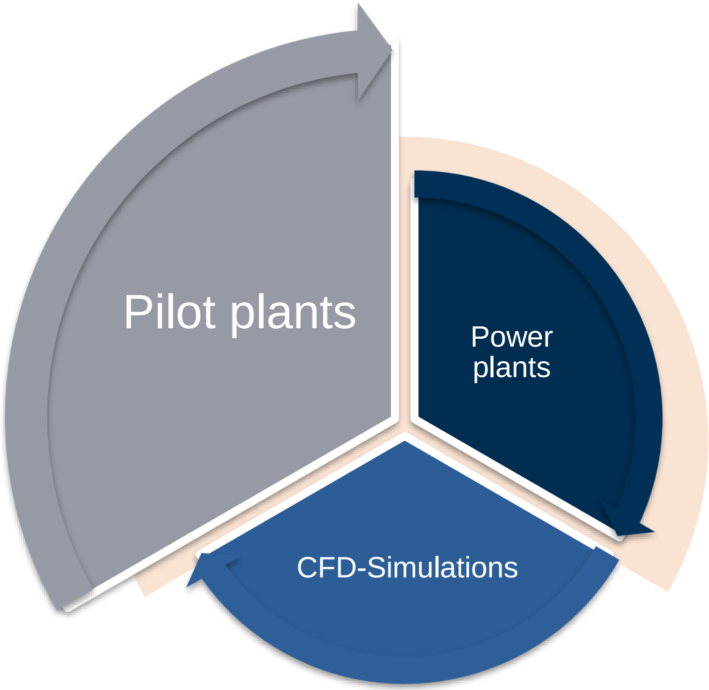
Technological evaluation and economic recommendation

OptiNOx

Pilot plants:

- Combustion of fuel in different pilot-scale plants
- Measurement of NO_x precursor species (NH_3, HCN)
- Investigation of primary and secondary measures to reduce emissions

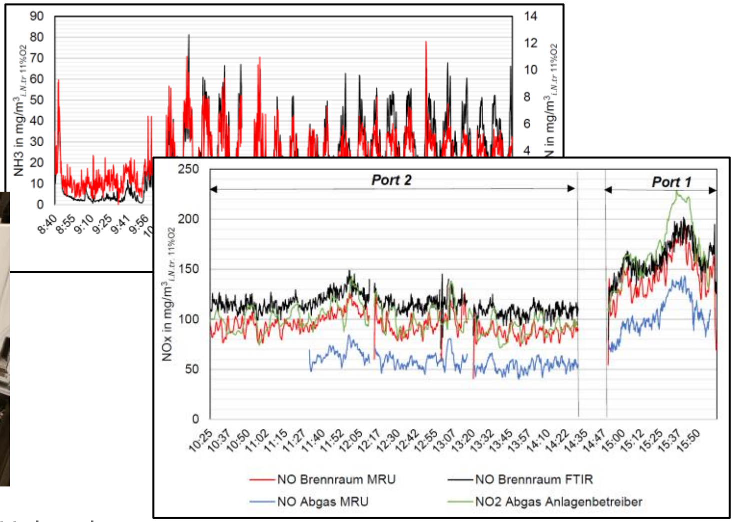


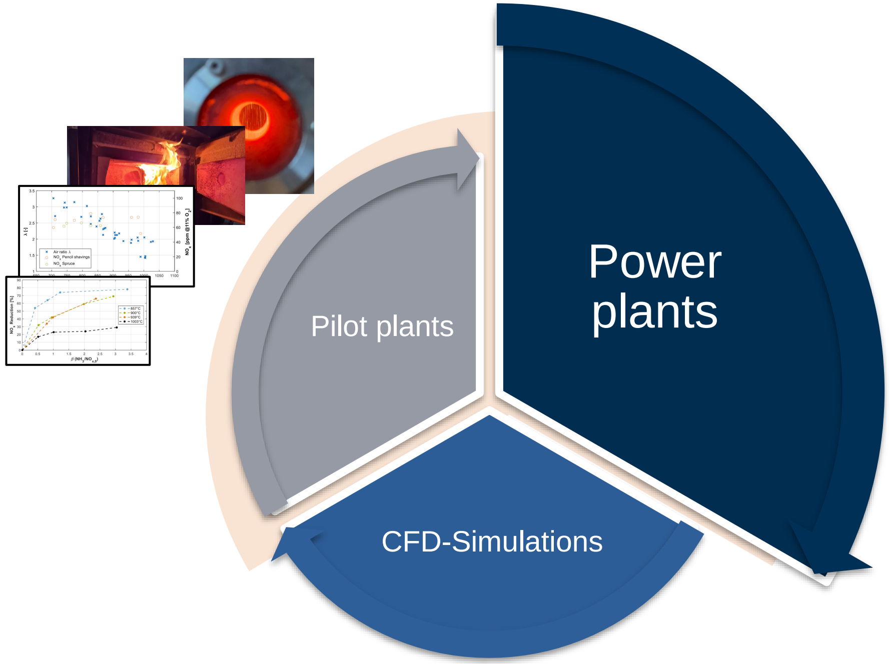


OptiNOx

Power Plants:

- Measurements of NO_x precursor species at different power plants
  - Skærbæk Power Plant (vibrating grate, 154 MW)
  - Avedøre Unit 2 (Straw Boiler) (vibrating grate, 105 MW)
  - Altenstadt HKW (fluidized bed, 49 MW)
  - Staedtler Residue Pencil Wood (injection furnace, 850 kW)



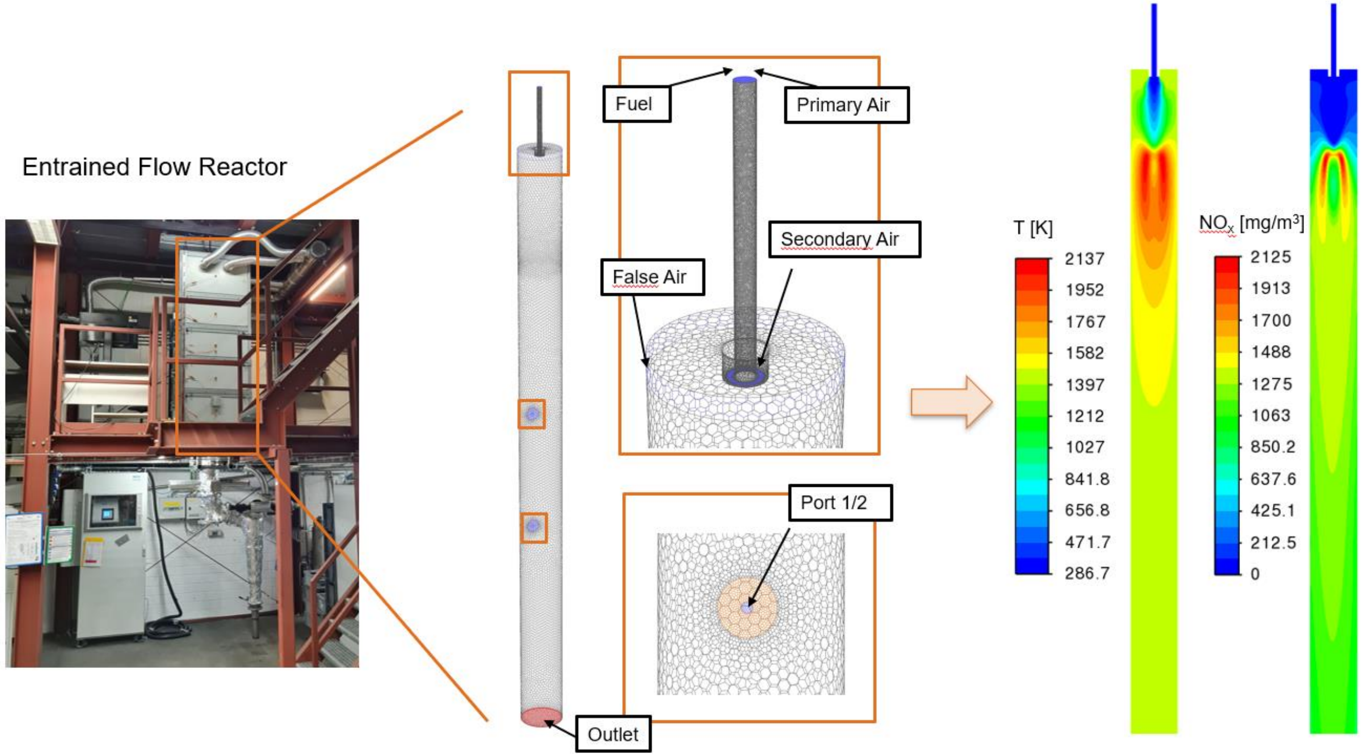


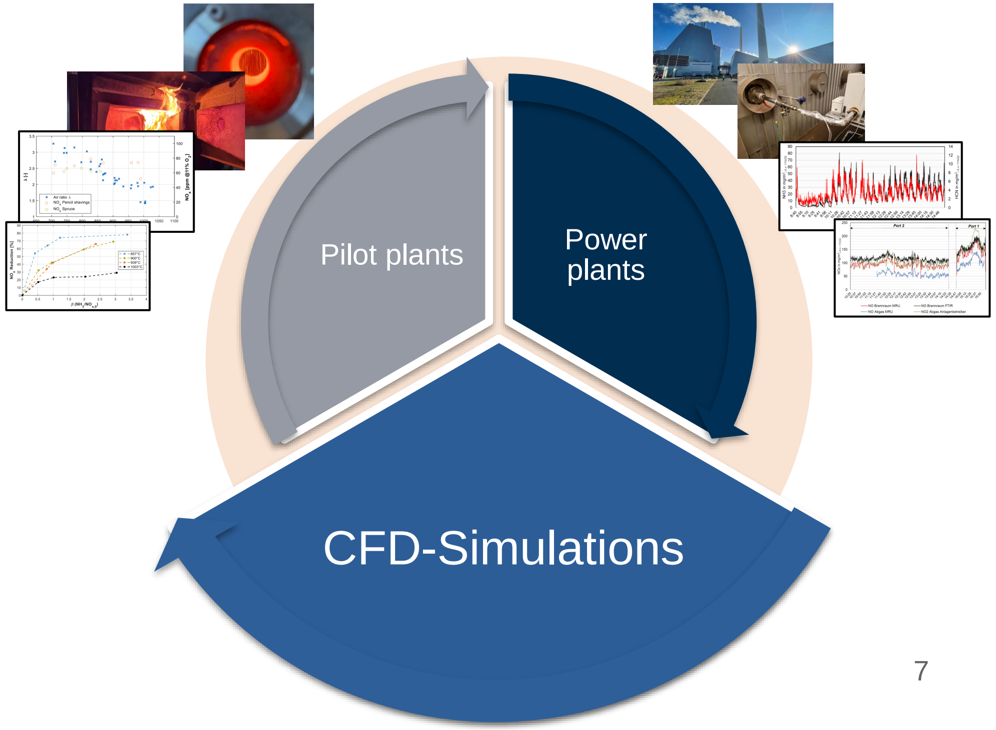
OptiNOx

CFD-Simulations:

- ➢ Development of NO_x and burnout models
- ➢ Simulation of pilot plants → Validation with the gained experimental data

Scale-Up and Optimization of the power plants

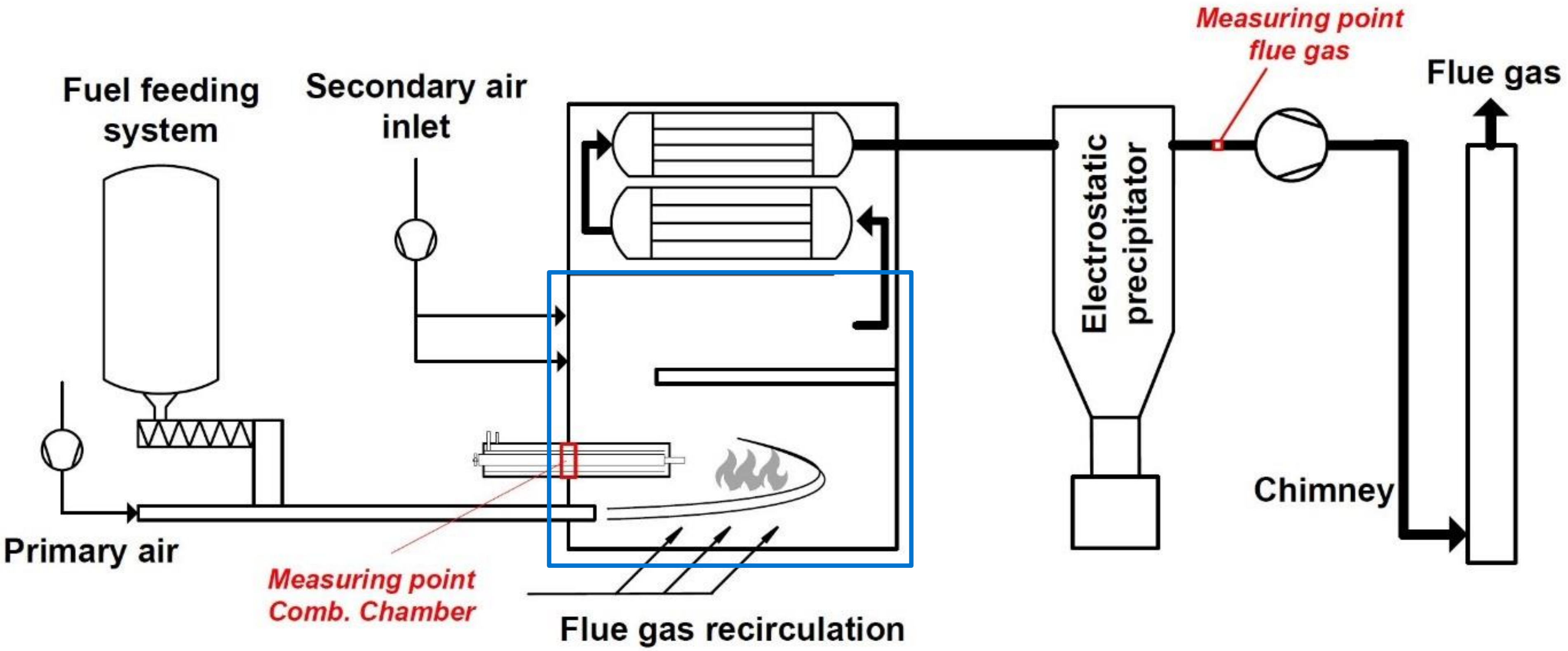




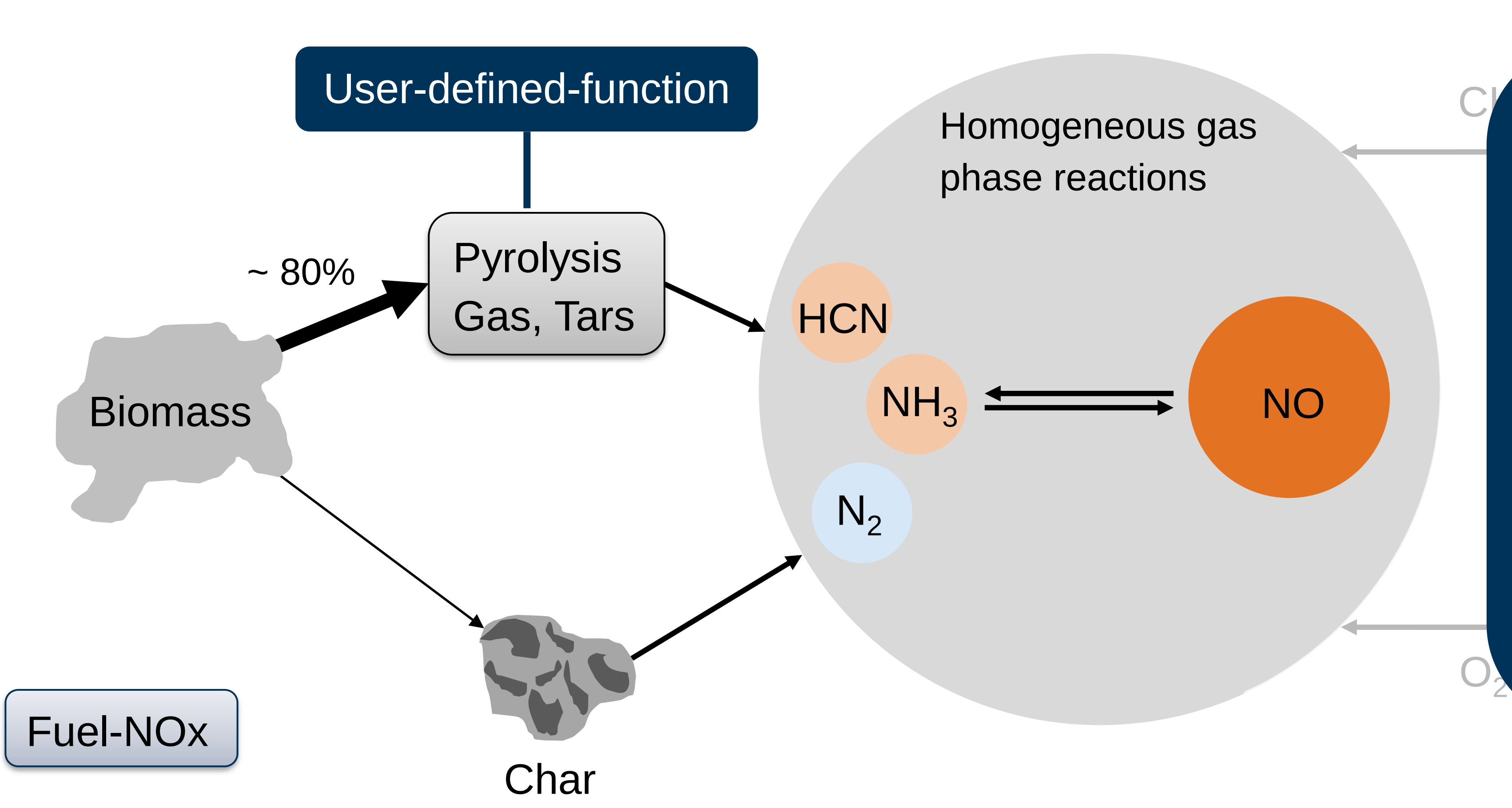
Staedtler – 850 kW Injection Furnace

- Combustion of wood residues from pencil production
- Air-Staging and Flue gas recirculation for control of emissions
- Two-point measurement has been conducted

C	52.14	wt.-%
H	5.52	wt.-%
O	33.66	wt.-%
N	0.94	wt.-%
S	0.44	wt.-%
v	**79.79**	**wt.-%**
a	0.33	wt.-%
f	6.44	wt.-%
HHV	20.35	MJ/kg



CFD-Model – NOx formation



UDF:

- Formation of different species
- Proportion of released Fuel-Nitrogen
- Releasing temperature
- Devolatilization kinetics

Model – NO_x Simulation

Combustion Simulation:
- Energy equation
- Turbulence Model (*realizable k-ε Model; Standard Wall Functions*)
- Radiation Model (*Discrete Ordinates*)
- Particle Tracking (*Discrete Phase Model; Discrete Random Walk Model*)
- Reaction Model (*Eddy Dissipation Concept; ISAT*)

Pollutant Simulation:
- Fixed temperature and velocity field
- Reaction Model (*Eddy Dissipation Concept; ISAT*)

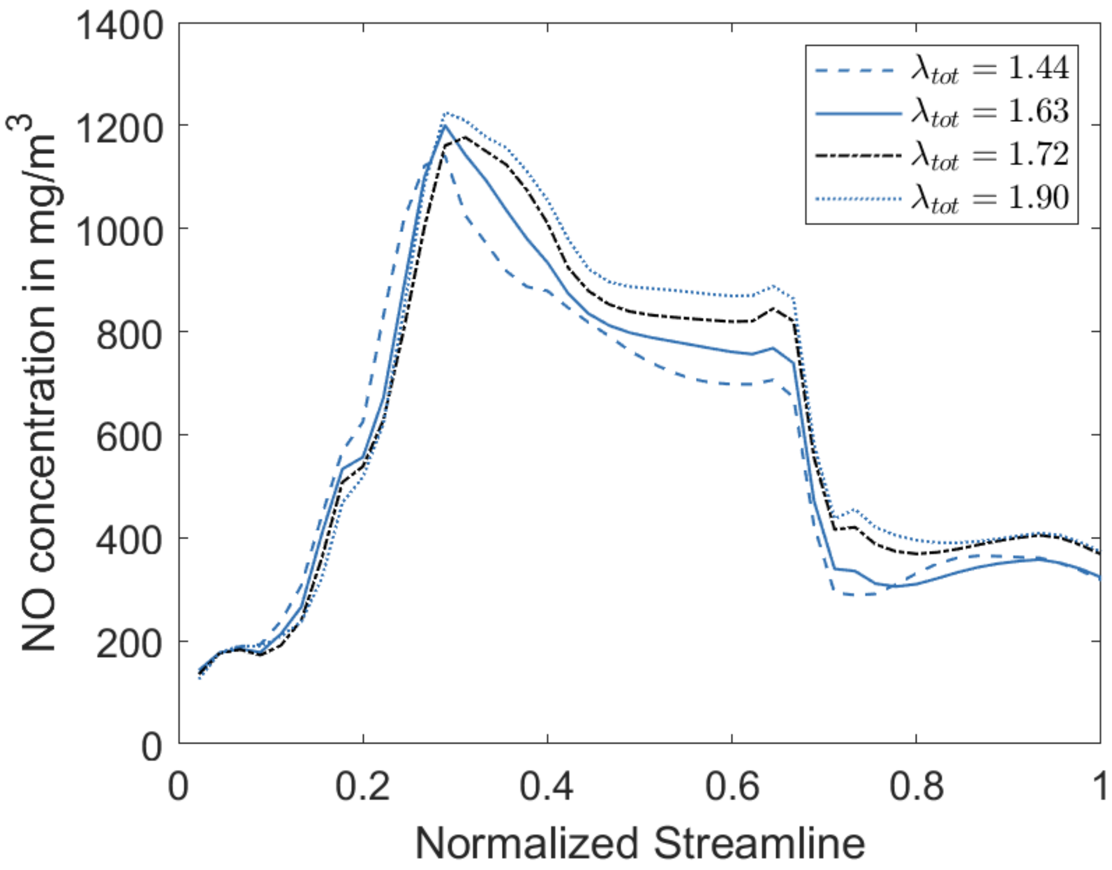
Global Reaction Mechanism: 10 species and 4 reactions

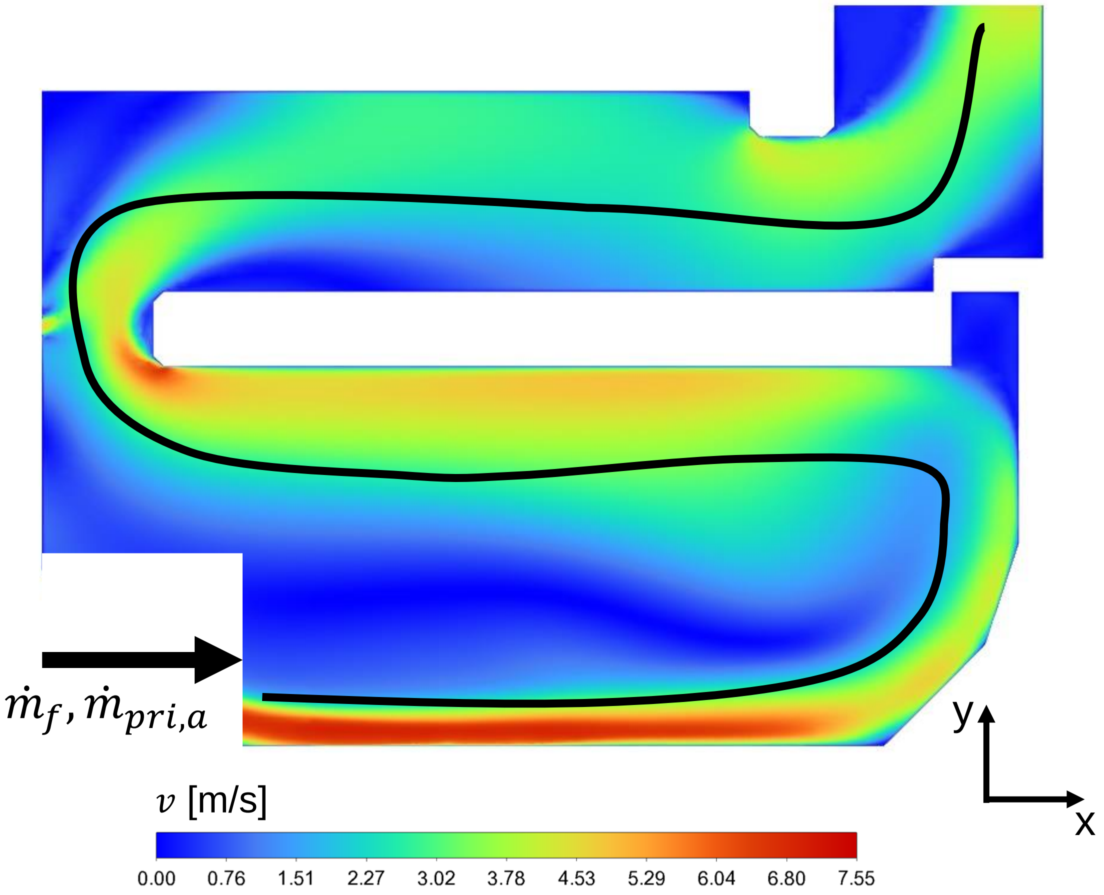
Skeletal NO_x Mechanism: 38 species and 168 reactions

Mesh independence study (850.000 cells) ✓

Influence of Fuel-Air Ratio

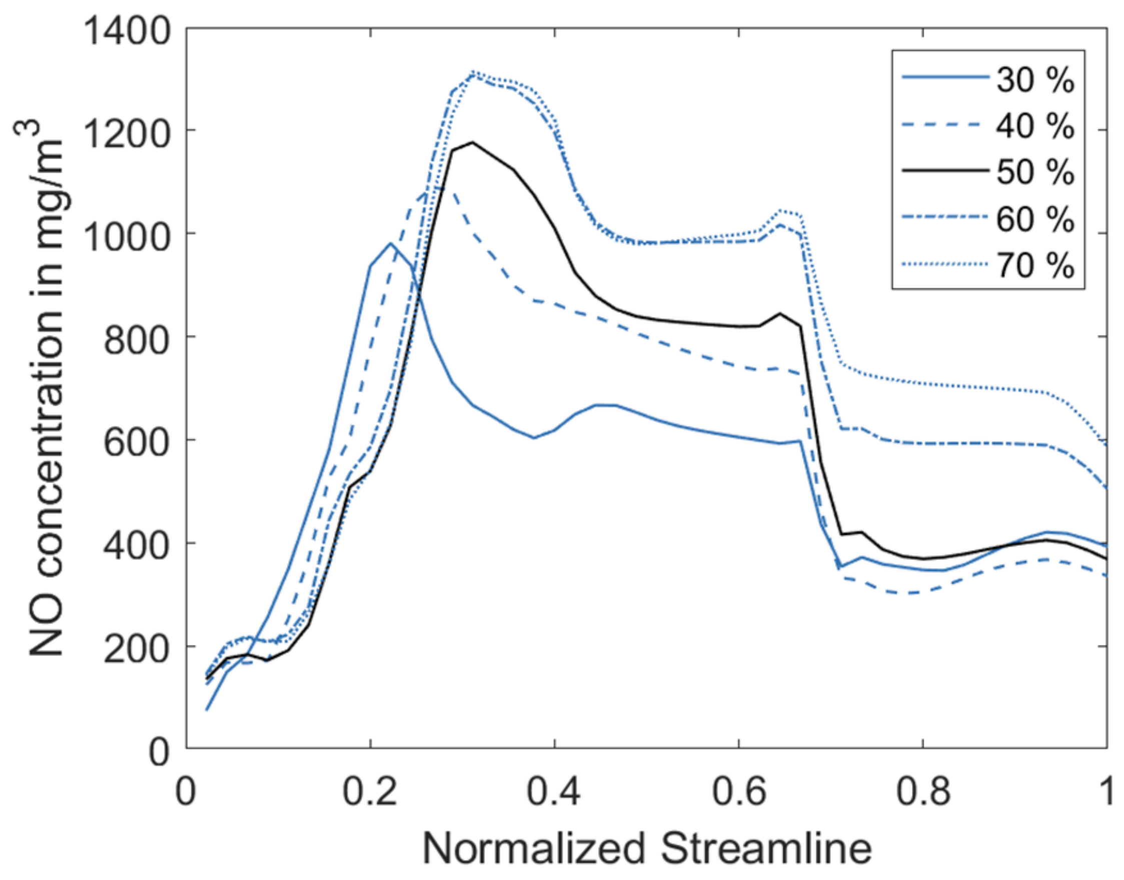
Fixed ratio of primary to secondary air (50:50)



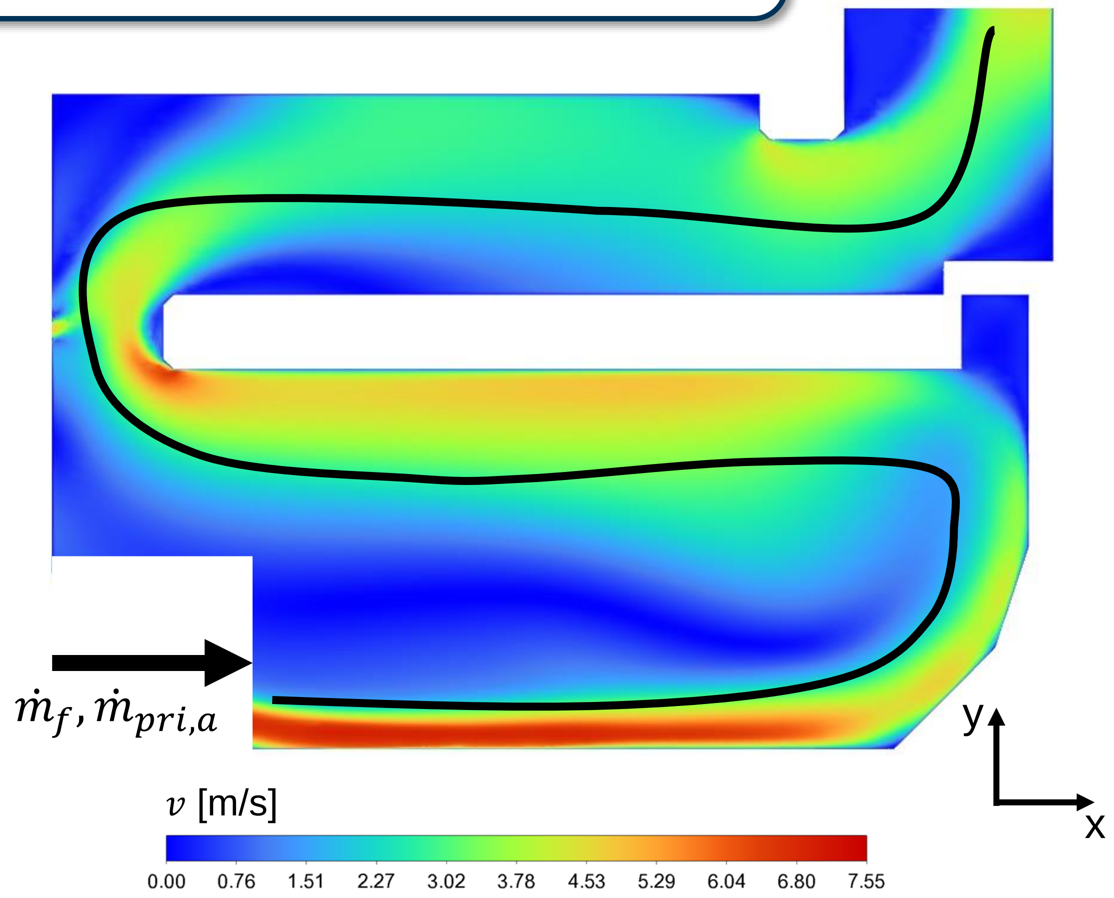


Influence of Air Staging

Fixed Fuel-Air Ratio with λ_{tot}= 1.7



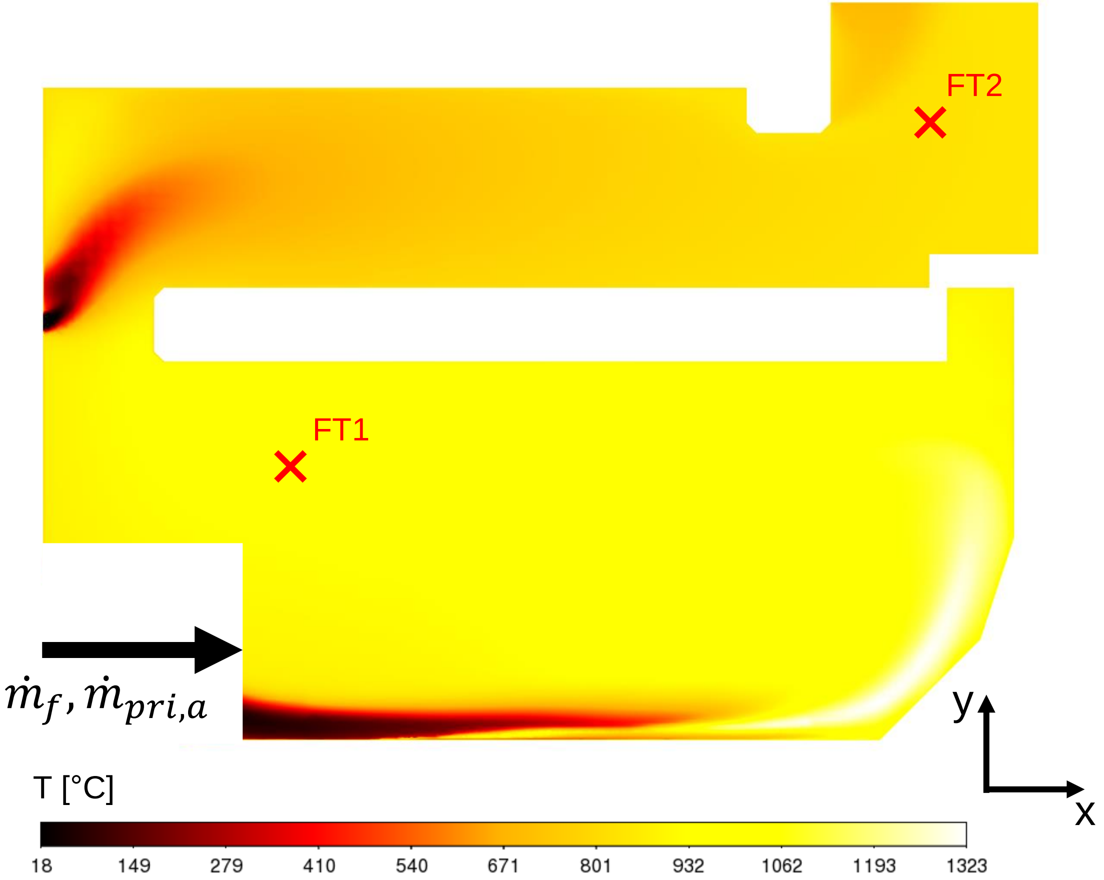
Optimal Ratio:
40% primary air to 60% secondary air



Scale-Up – Staedtler – 850 kW Injection Furnace

Fuel: Wood shavings from pencil production (N-Fraction: 0.94 wt.%)

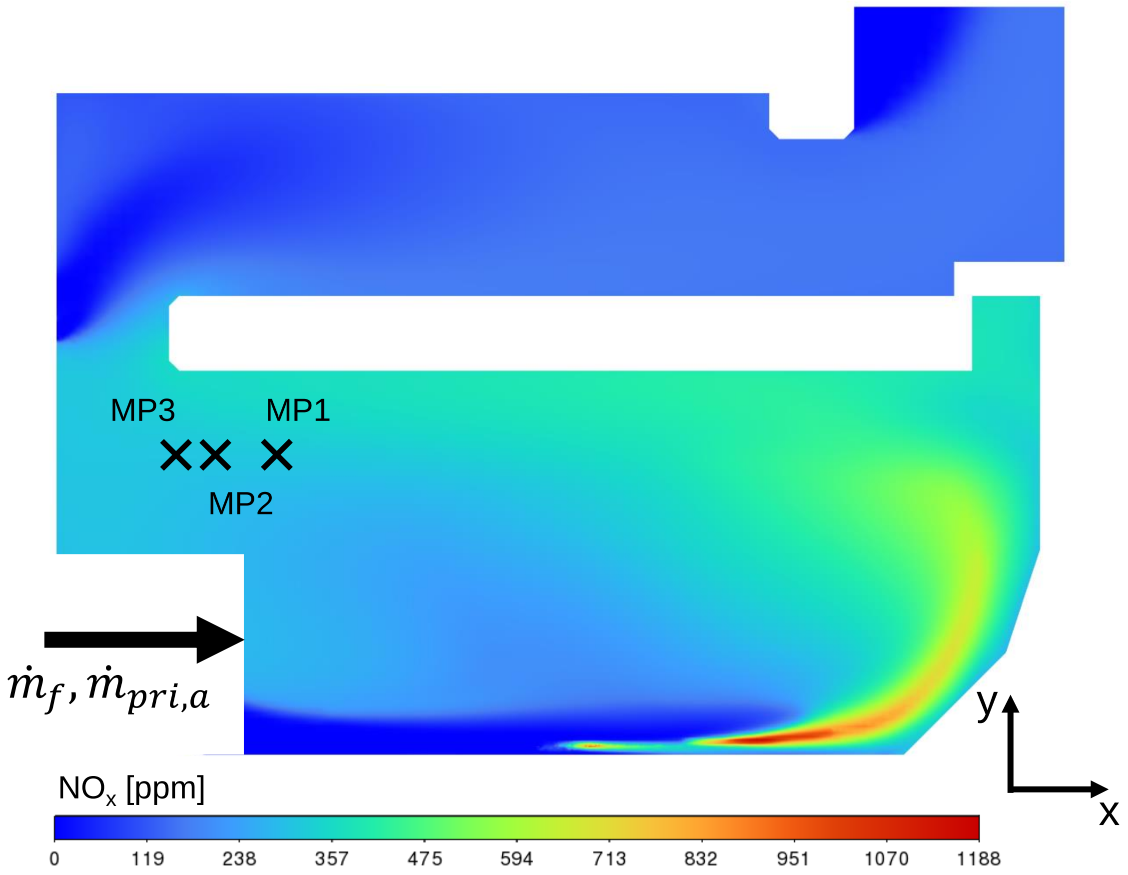
	Measurement	Simulation
Outlet		
CO_2 [%]	12.36	11.59
O_2 [%]	5.01	5.74
CO [ppm]	648.98	489.58
NO [mg/m^3 @6%O_2]	**127.01**	**278.94**
Temperature		
FT1 [°C]	1060.01	954.14
FT2 [°C]	892.75	831.26



Scale-Up – Staedtler – 850 kW Injection Furnace

Fuel: Wood shavings from pencil production (N-Fraction: 0.94 wt.%)

	Measurement	Simulation
MP1 (60cm)		
NO [ppm]	102.26	259.71
NH_3 [ppm]	70.88	159.73
HCN [ppm]	6.78	73.19
MP3 (30cm)		
NO [ppm]	92.43	265.87
NH_3 [ppm]	72.16	221.18
HCN [ppm]	5.26	97.86



Outlook

Comparison

- Model can be scaled up and used for modelling of injection furnaces
- Influence of Fuel-Air Ratio as well as Air-Staging was analyzed

  → Optimal Air-Staging Ratio could be identified

Next Steps:

- Compare with trends from new measurements at the power plant
- Include release of char-N and NO_x formation due to secondary tar cracking reactions
- Implement variable releasing temperatures for the species

Thank you for your attention!

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