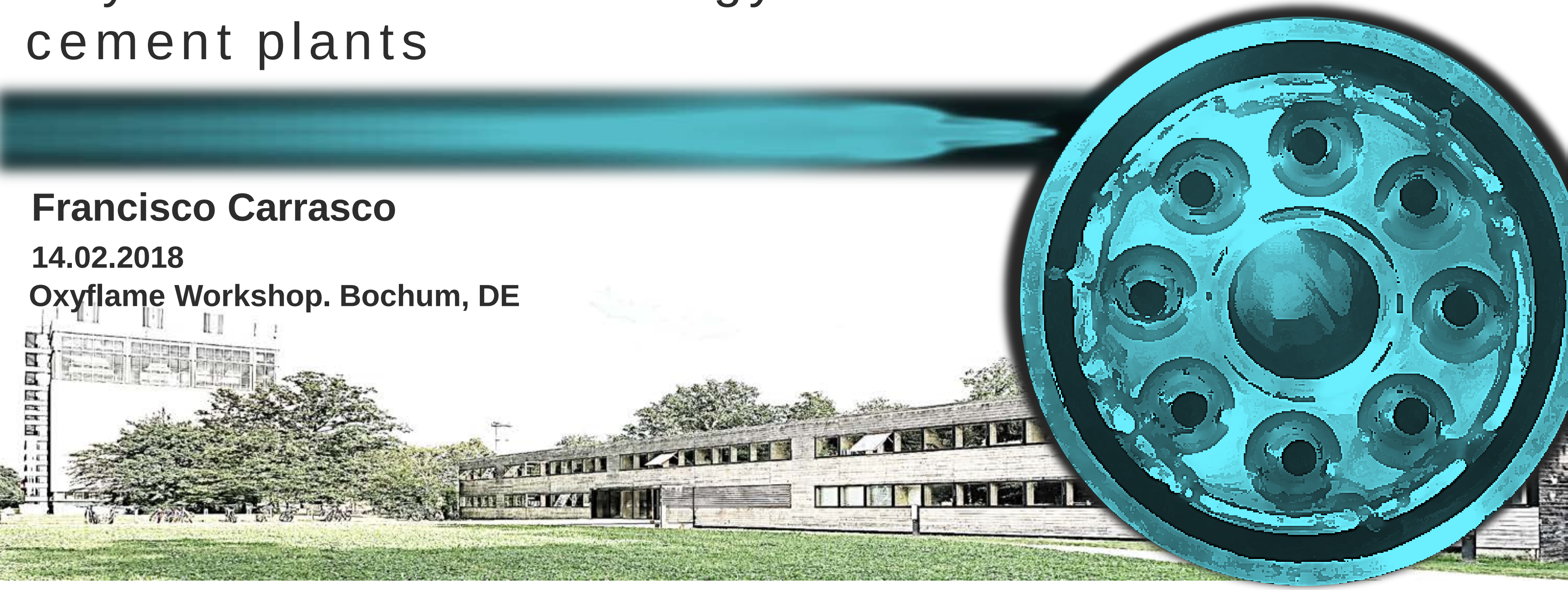
University of Stuttgart
Institute of Combustion and Power Plant Technology
Prof. Dr. techn. G. Scheffknecht

Oxyfuel burner technology for cement plants



Francisco Carrasco

14.02.2018
Oxyflame Workshop. Bochum, DE

Outline

Motivation

Objective

Test facility and burner geometry

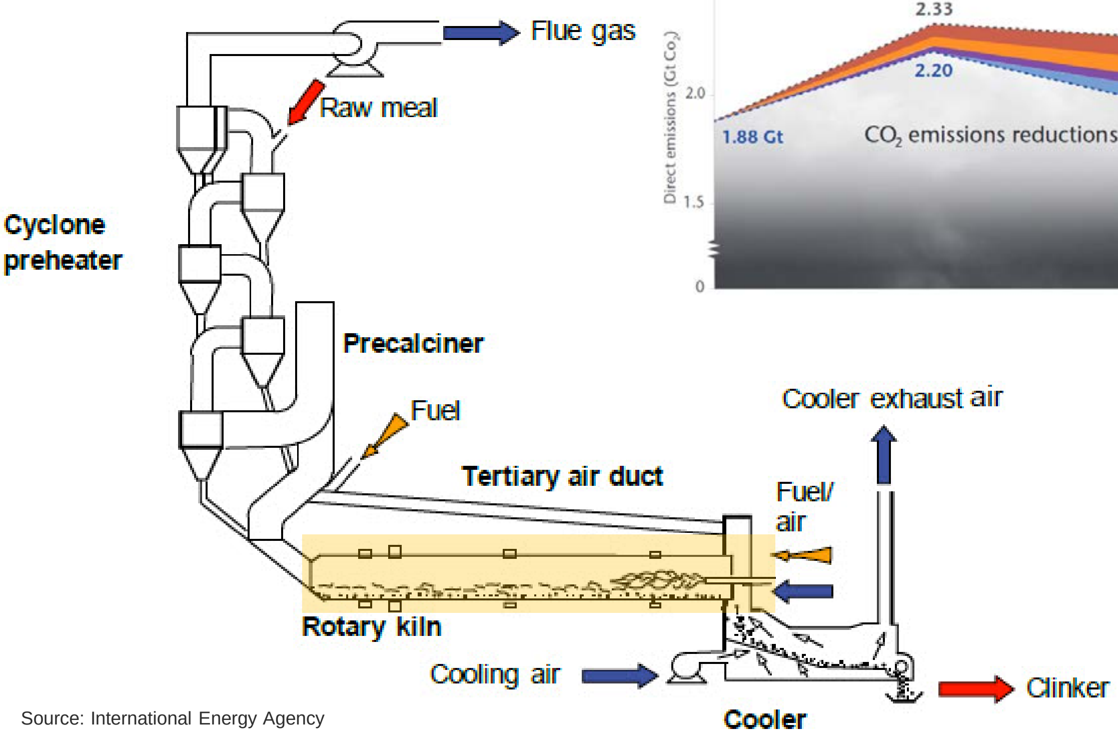
Results

Conclusions

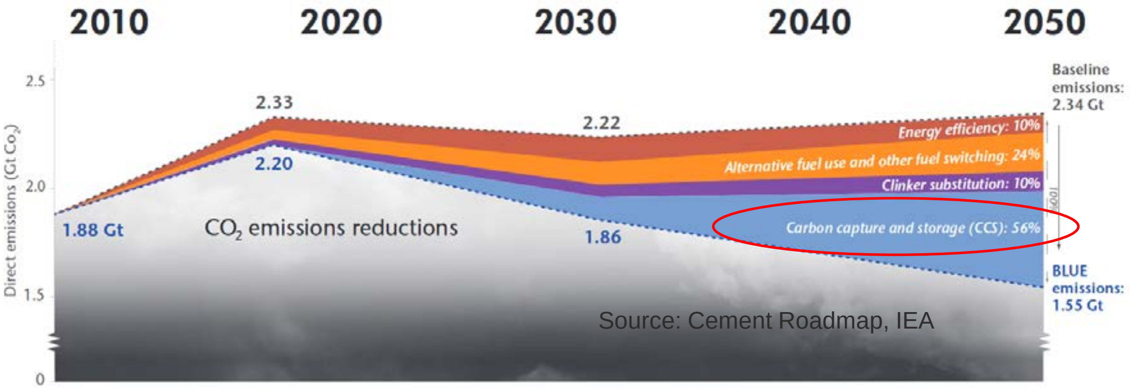
Motivation

Motivation

50% of CO_2 =>
decomposition of limestone



Source: International Energy Agency



Source: Cement Roadmap, IEA

1 ton of cement → 0,6 - 0,7 tons of CO_2

Motivation

First oxy-cement plant envisaged in 2020-2025.

Technologies investigated:

- **Postcombustion**
  - Chilled ammonia
  - Membrane-assisted CO2 liquefaccion
  - Calcium looping
- **Oxyfuel**

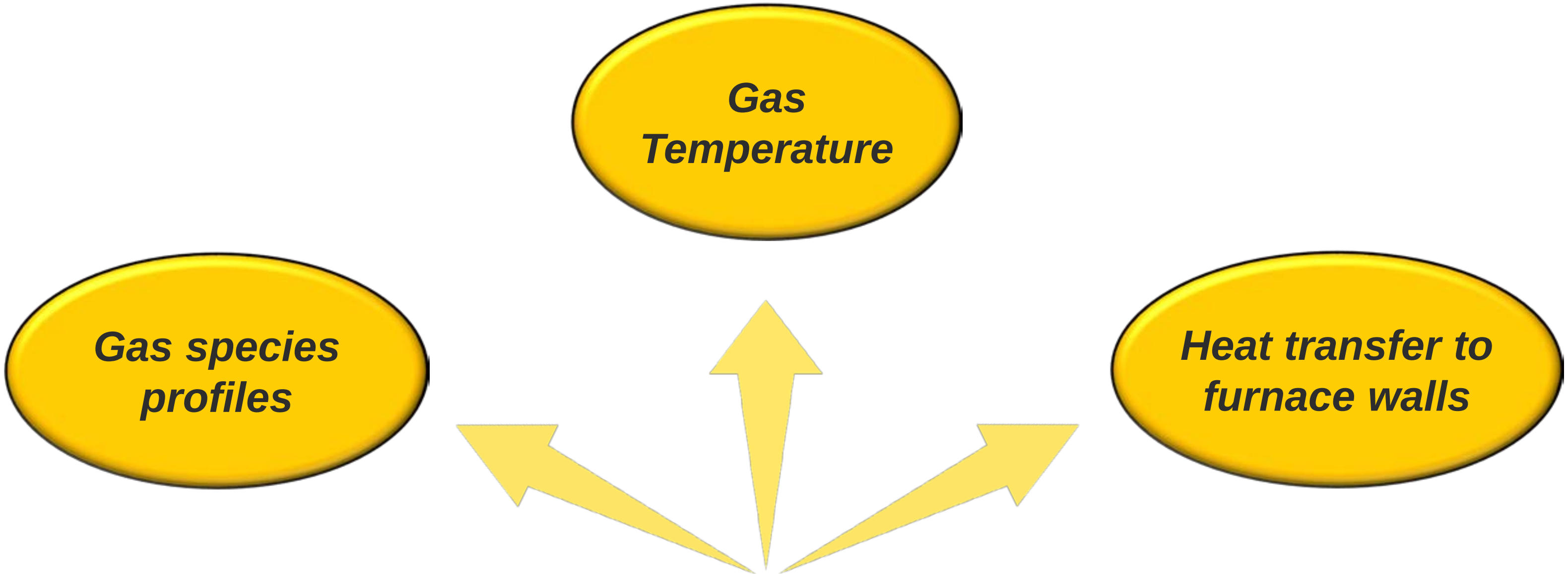
CEMCAP

CO_2 Capture from Cement Industry

Objective

Objective

Evaluate suitability of using modern burner design (multi-nozzle) for oxyfuel operation.



Gas Temperature

Gas species profiles

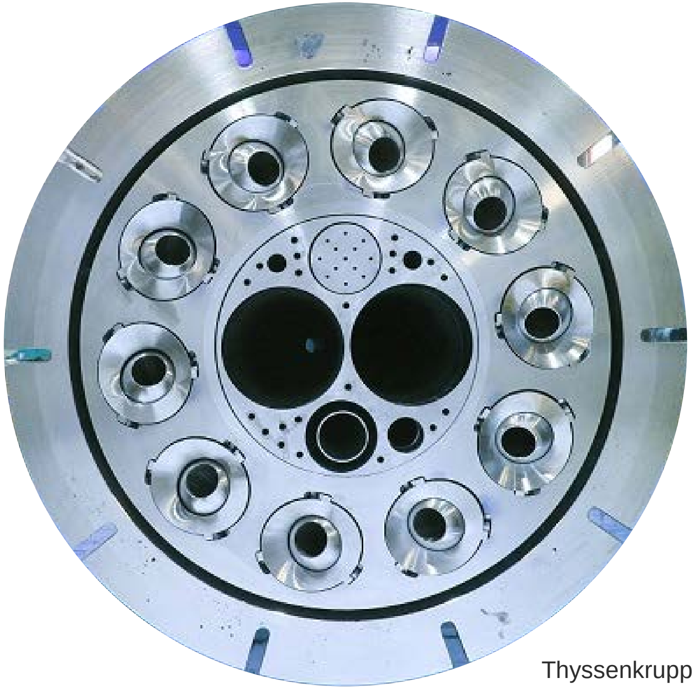
Heat transfer to furnace walls

Downscaling of rotary kiln burner
Assessment of Combustion behavior

Burner and test facility

Burner

	Industry	IFK-Pilot facility
Burner Diameter [m]	1.1	0.075
Ratio of Diameters [-]	5	11
Thermal Load [MW]	47	0.5
Burner momentum [N/MW]	6-14	10



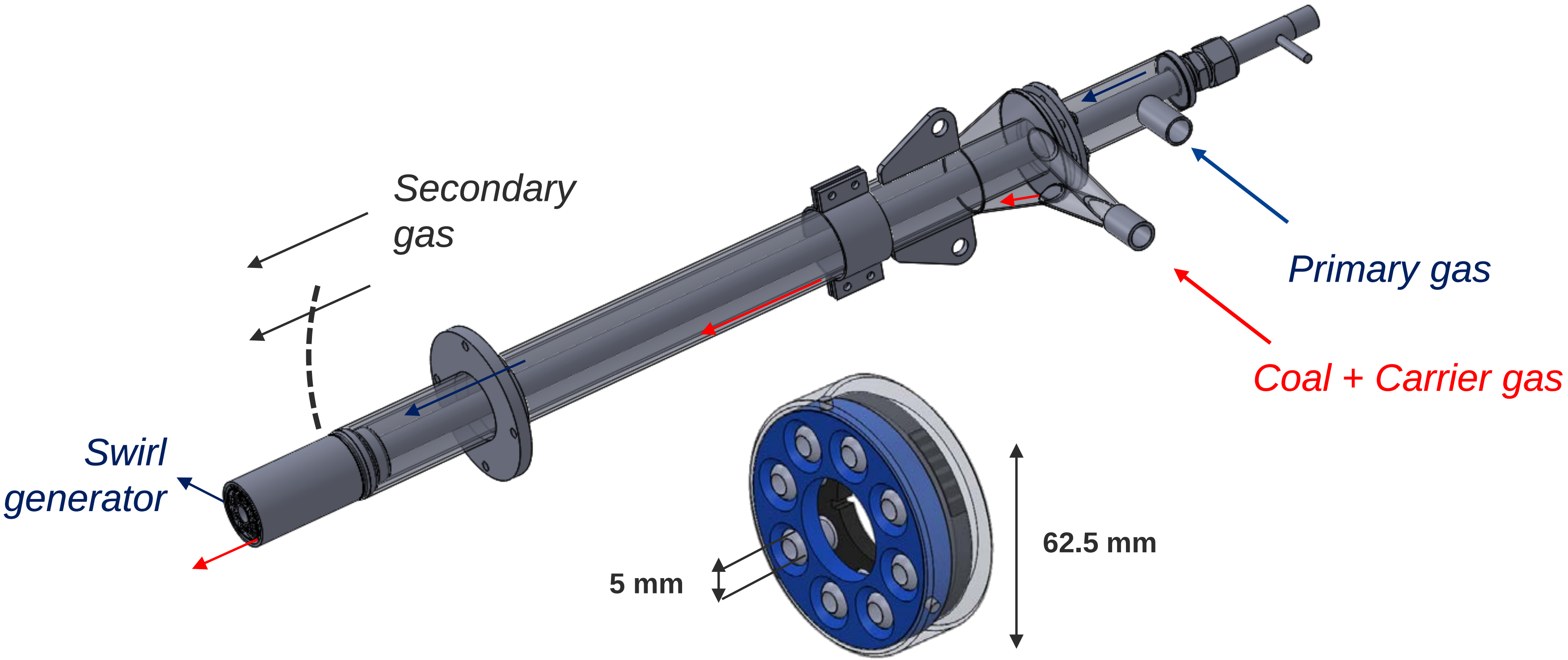
Thyssenkrupp

Downscaled burner
for IFK-KSVA

Downscaling criteria:

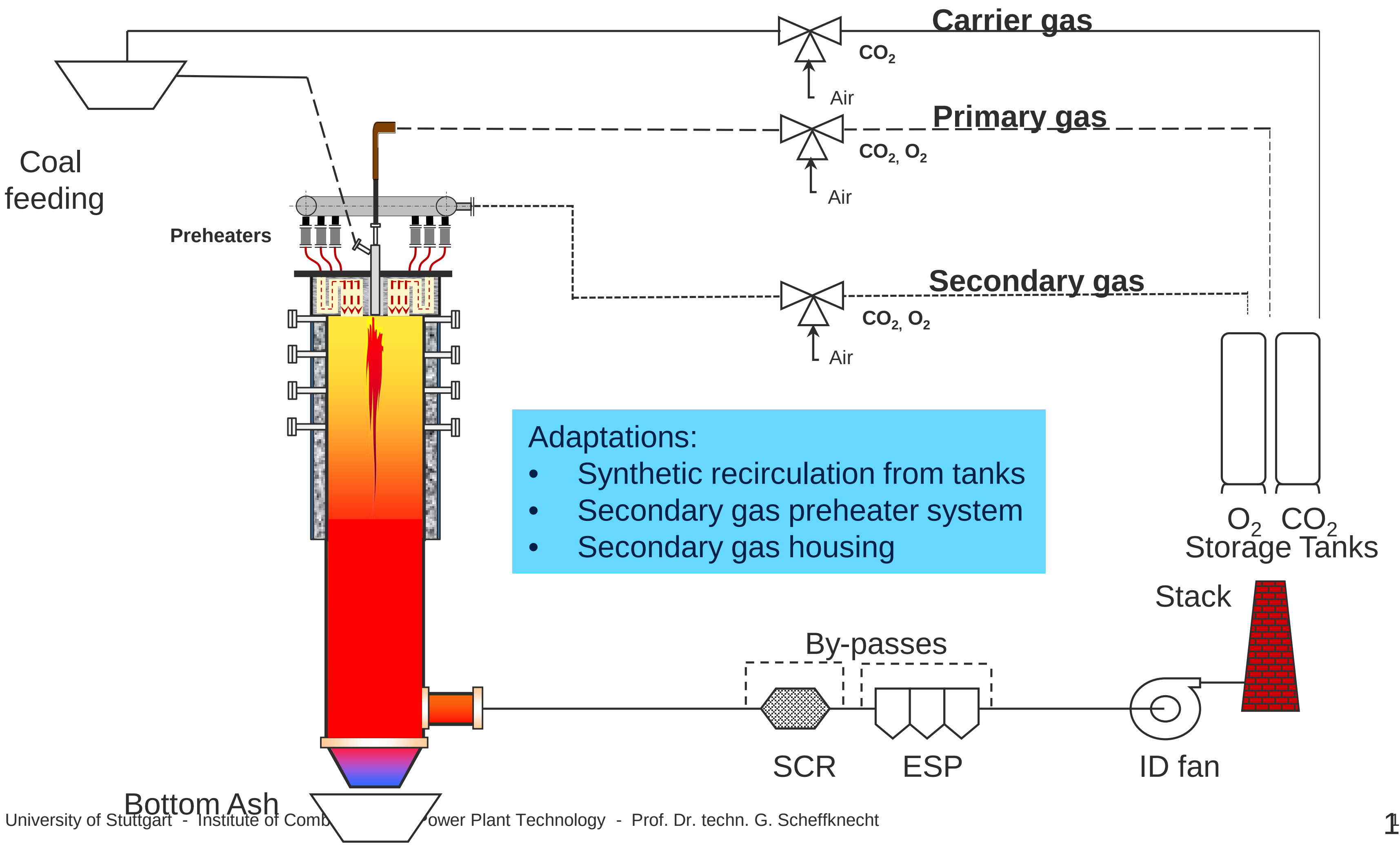
- Burner momentum (outlet velocities)
- Swirling (0-40°)

Burner assembly



0° to 40° nominal swirl

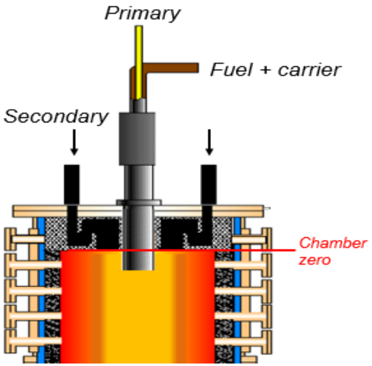
Test setup



Adaptations:

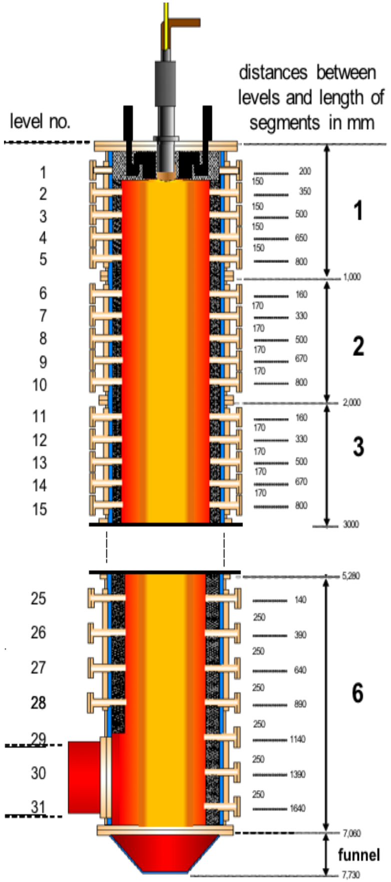
- Synthetic recirculation from tanks
- Secondary gas preheater system
- Secondary gas housing

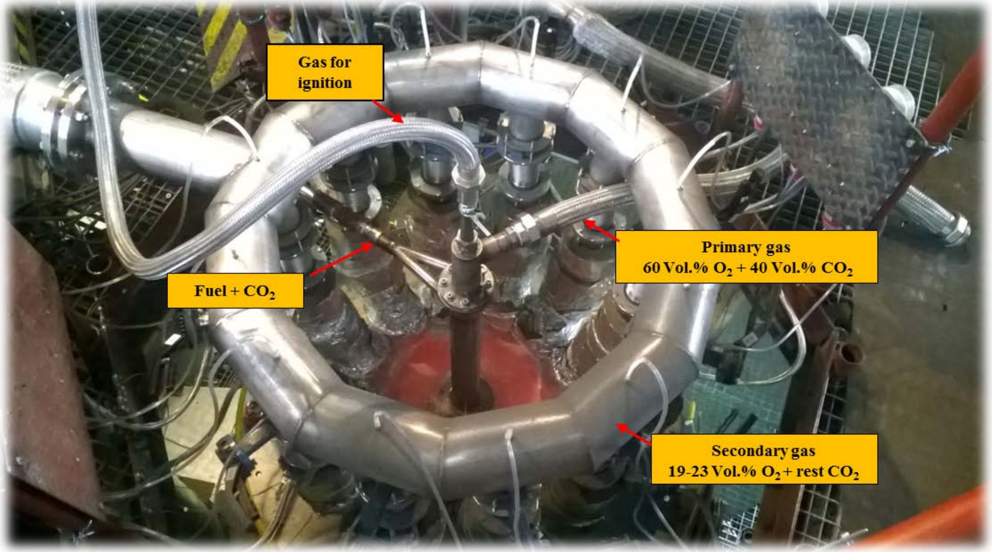
Test cases



		Air	OF29	OF32
Fuel thermal input	kW	400	400	400
Primary gas composition	Vol.-%, wet	Air	60% O_2 + 40% CO_2	60% O_2 + 40% CO_2
Secondary gas composition	Vol.-%, wet	Air	20% O_2 + 80% CO_2	24% O_2+ 76% CO_2
Fuel carrier gas composition	Vol.-%, wet	Air	100% CO_2	100% CO_2
λ (air to fuel ratio)	-	1,10	1,10	1,10

Test set-up


level no.
distances between levels and length of segments in mm
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
25
26
27
28
29
30
31
200
150
350
150
500
150
650
150
800
1,000
160
170
330
170
500
170
670
170
800
2,000
160
170
330
170
500
170
670
170
800
3000
5,280
140
250
390
250
640
250
890
250
1140
250
1390
250
1640
7,060
7,730
1
2
3
6
funnel


Gas for ignition
Primary gas
60 Vol.% O_2 + 40 Vol.% CO_2
Fuel + CO_2
Secondary gas
19-23 Vol.% O_2 + rest CO_2

Fuel characterisation

- German pre-dried lignite

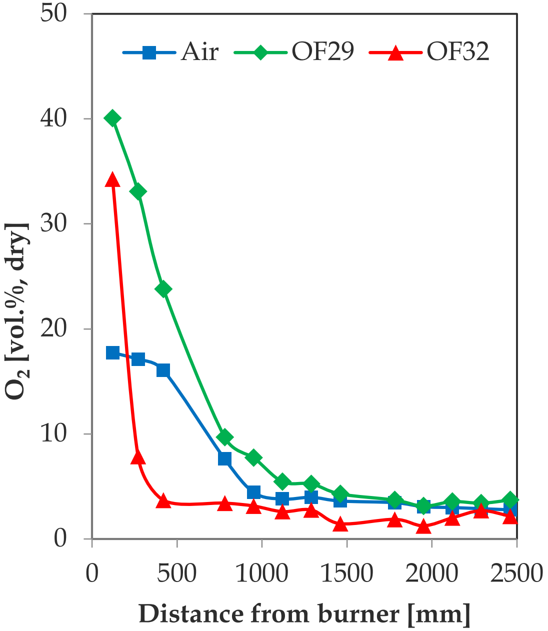
	an	wf
NCV [MJ/kg]	22,200	24,860
Water [%]	10,7	-
Ash [%]	3,02	3,38
Volatiles [%]	46,6	52,1
Cfix [%]	39,7	44,5
C [%]	58,4	65,4
H [%]	4,25	4,76
N [%]	0,702	0,786
S [%]	0,317	0,355

	PSD
D10	6 µm
D50	30 µm
D90	150 µm

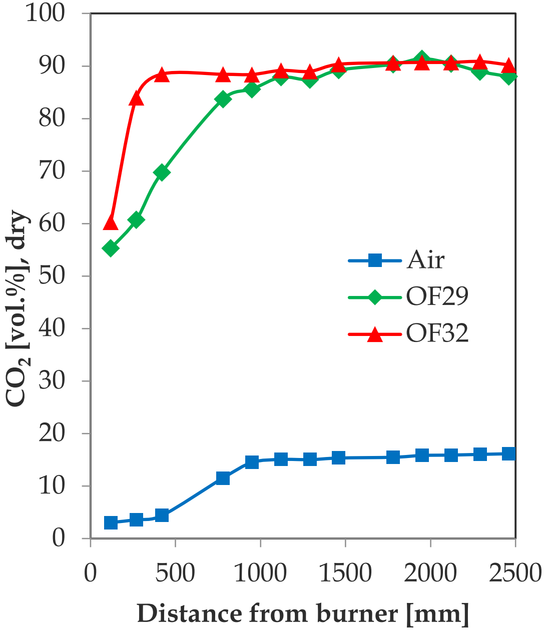
Results

Species concentration
(centerline)

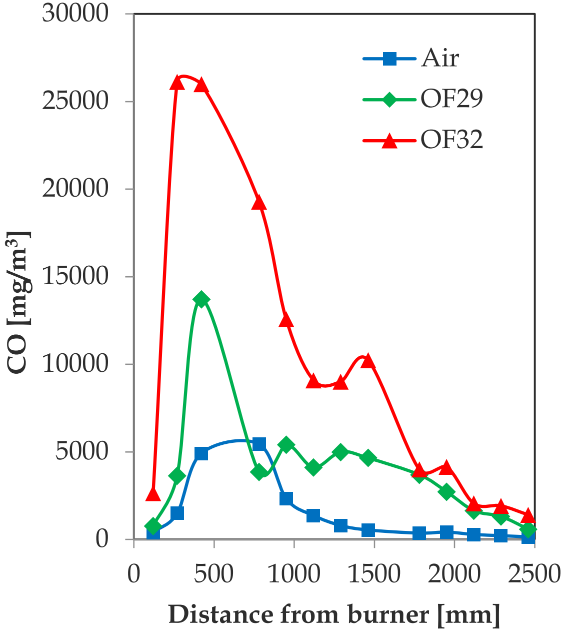
Oxygen



Carbon Dioxide

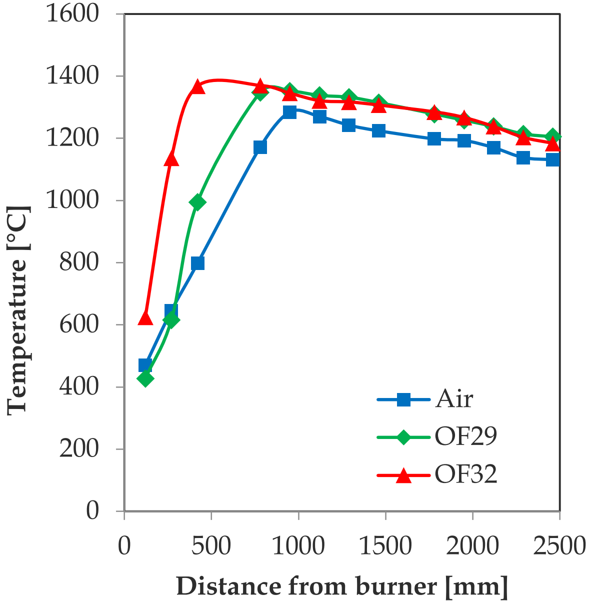


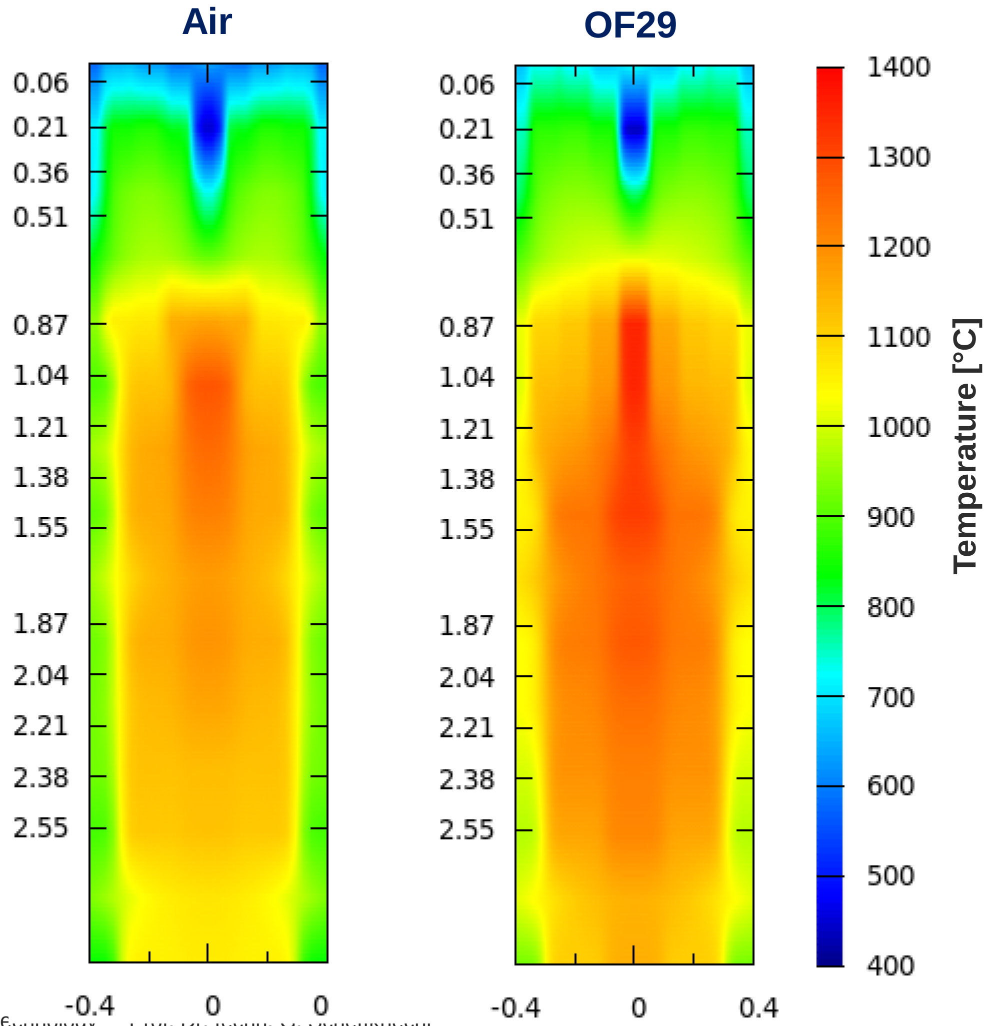
Carbon Monoxide



Gas temperature

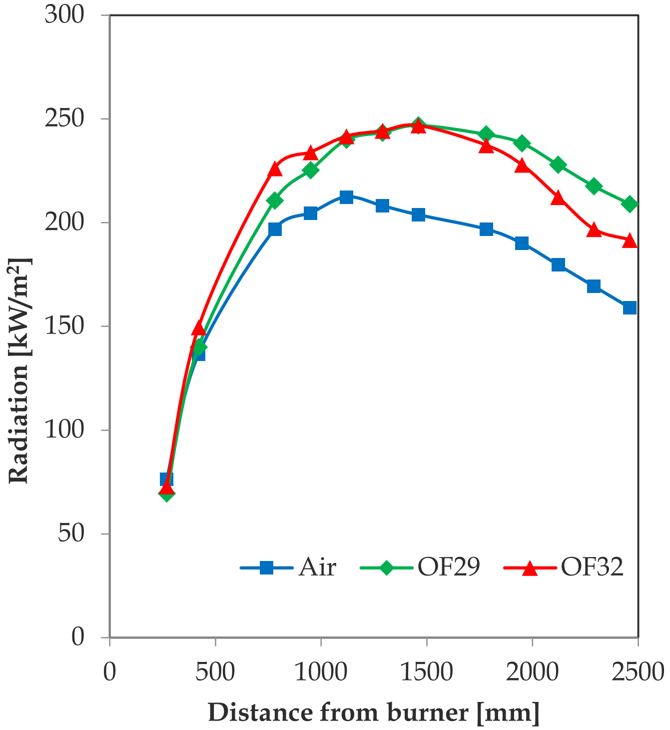
(centerline)

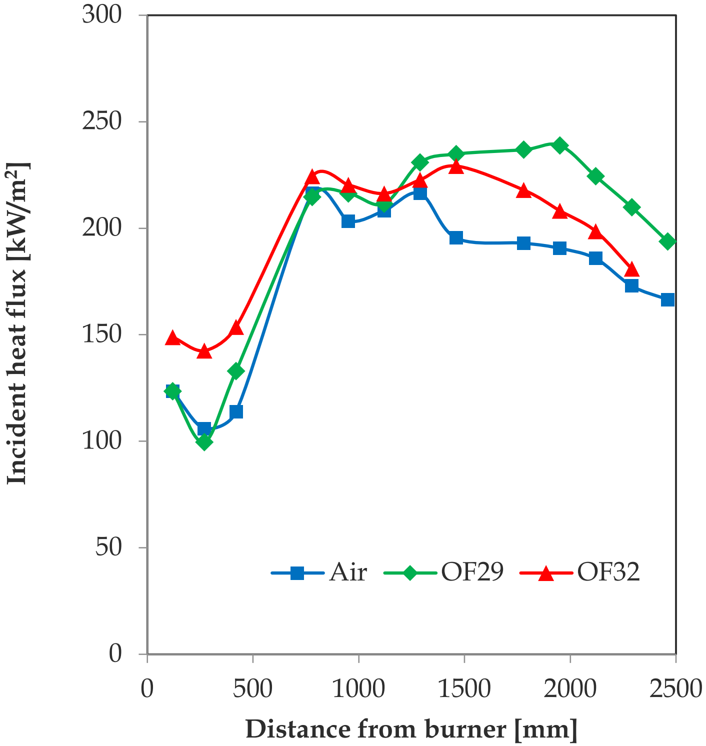




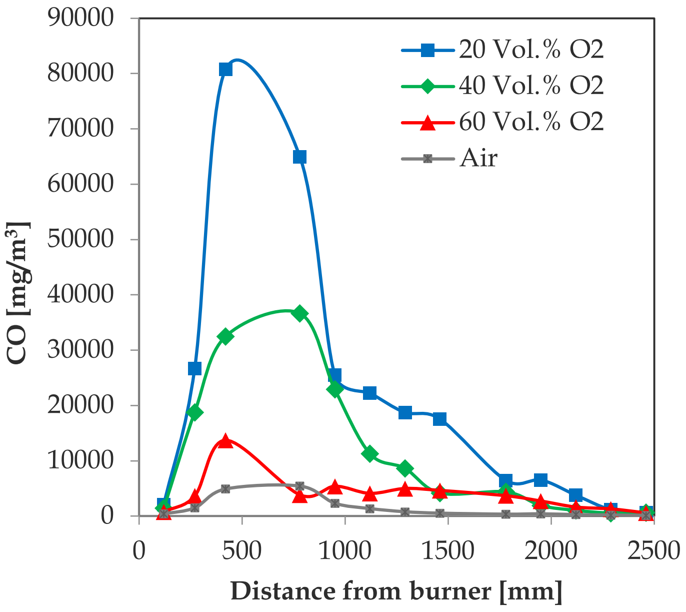
Incident heat flux

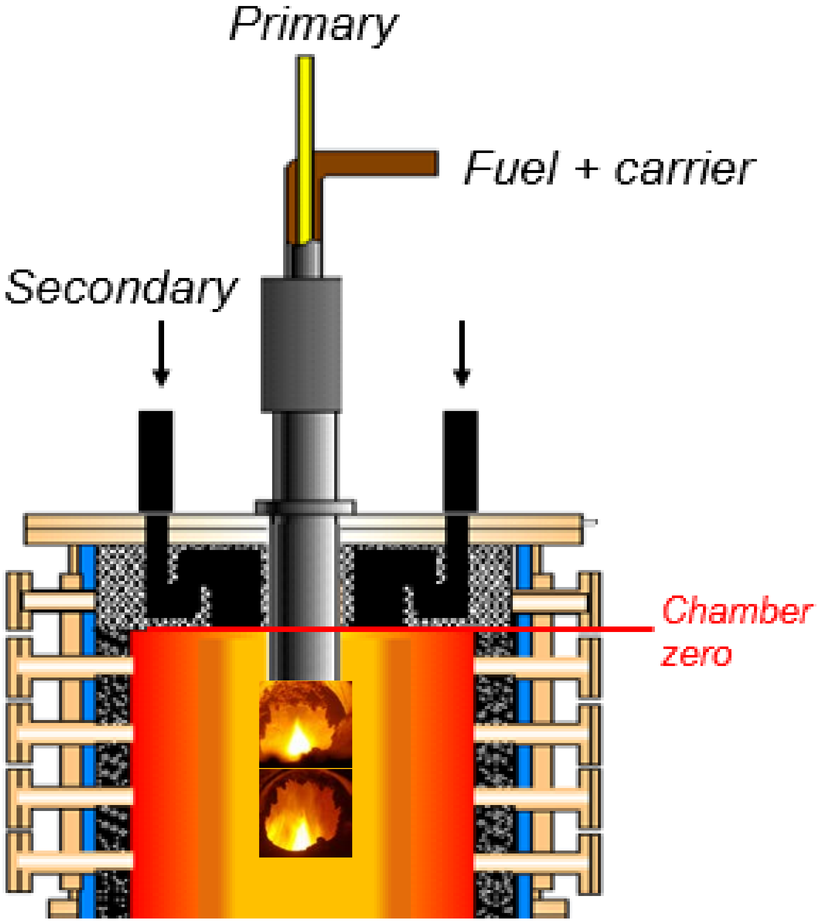
(measured at the wall)





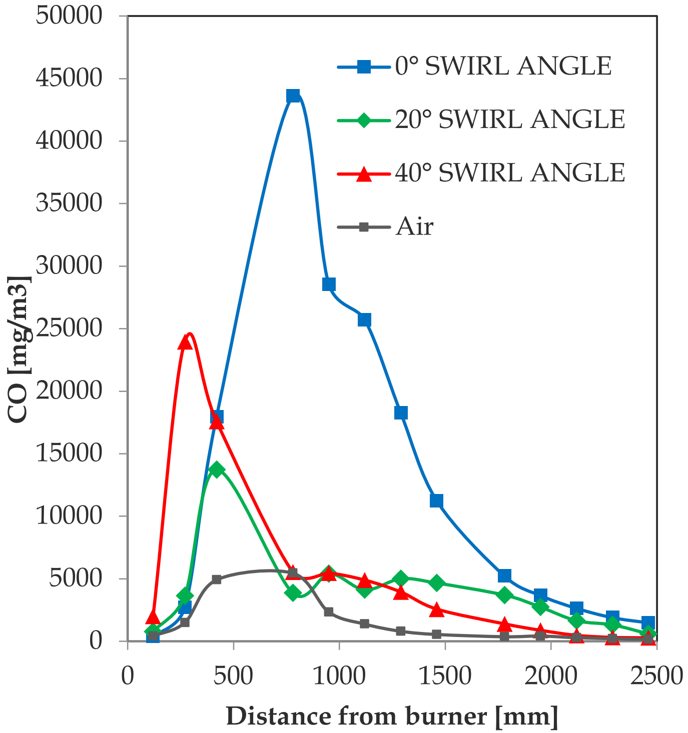
Oxygen enrichment in PG during OF29
(centerline)

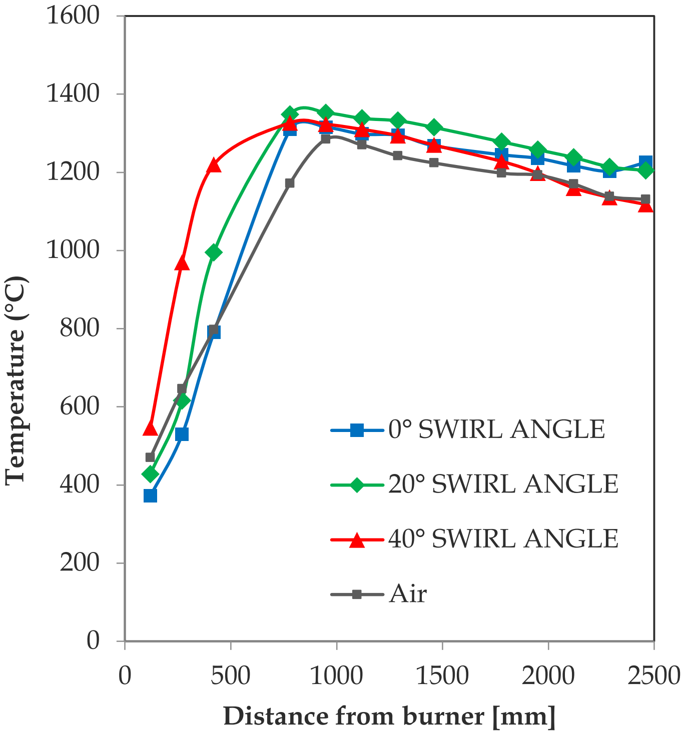




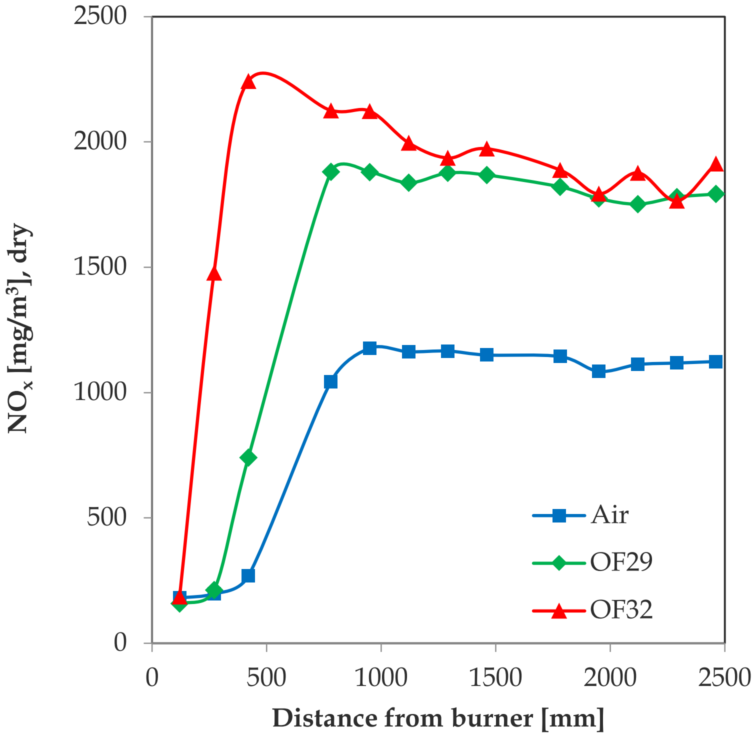
Swirl angle variation in PG for OF27

(centerline)

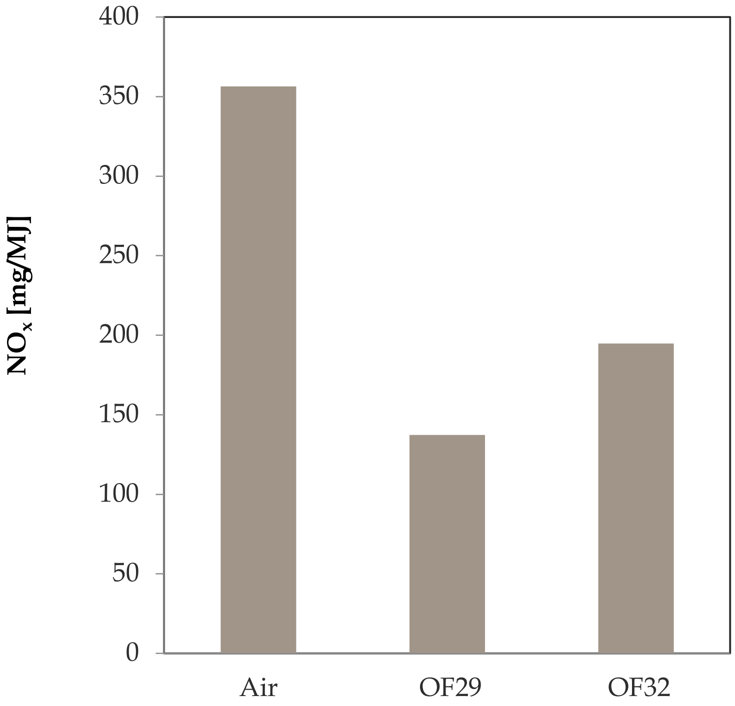




Nitrogen oxides
(centerline)



Flue gas reduction considered:



Conclusions

Conclusions

- Tested jet burner design could be used for oxyfuel operation without modifications necessary.
- Total oxygen content, gas distribution in burner outlets and swirl angle are useful adjustable parameters in order to obtain similar temperature, flame formation and heat transfer behavior as in air combustion.
- Lower total oxygen enrichment (OF25-27) should be used to obtain similar incident heat flux to the walls as in air operation.
- Oxygen enrichment in primary gas (60 vol.%) favors fuel oxidation to CO_2 (dominance of heterogeneous gasification reaction $C_{(s)} + CO_2 \rightarrow 2CO$ is mitigated).
- For tested OF conditions NO_x emissions are reduced in ~50% when considering flue gas reduction due to recirculation conditions.

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Thank you!

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