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Oxy-fuel Investigations with a Cement Kiln prototype Burner

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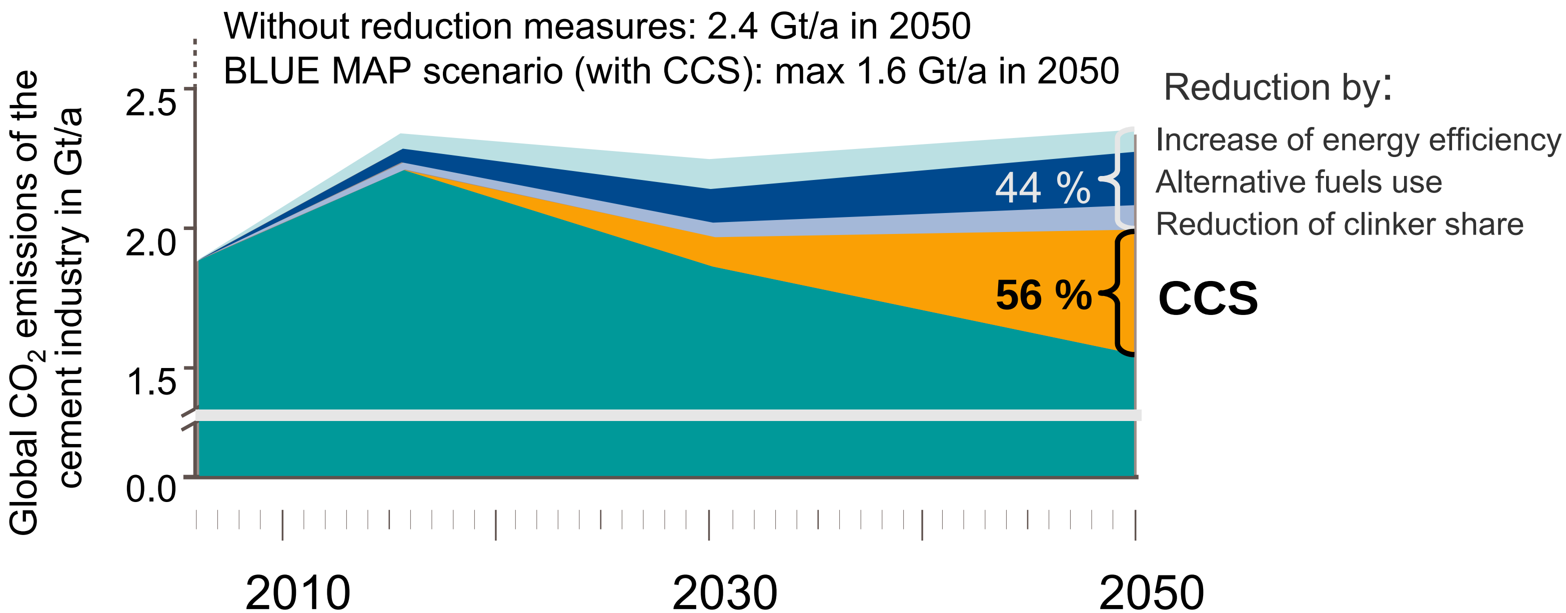
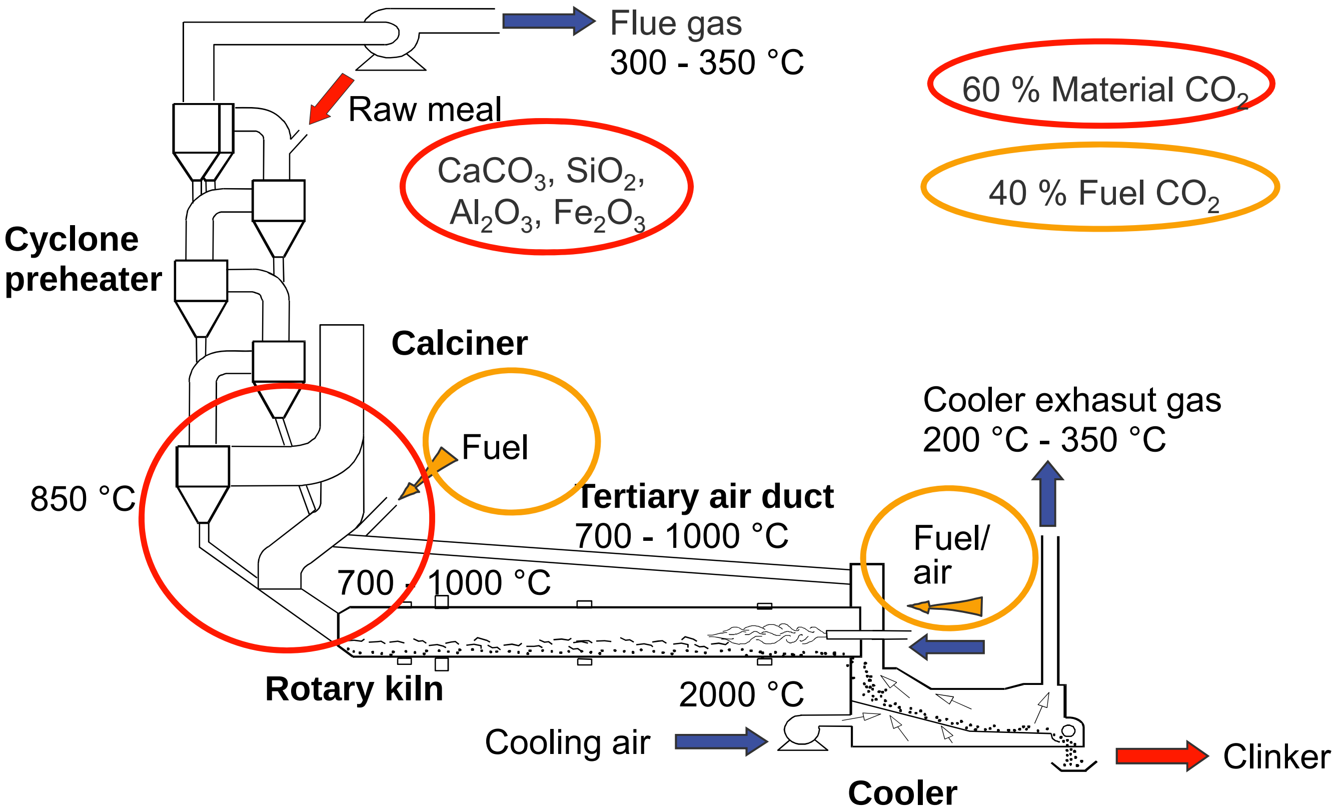
Oxy-fuel for cement production?



Source: IEA Cement Roadmap

- IEA target for 2050: 50 % of all cement plants in Europe, Northern America, Australia and East Asia apply CCS
- Cement plants typically have a long lifetime (30-50 years or more) and very few (if any) are likely to be built in Europe → Retrofit

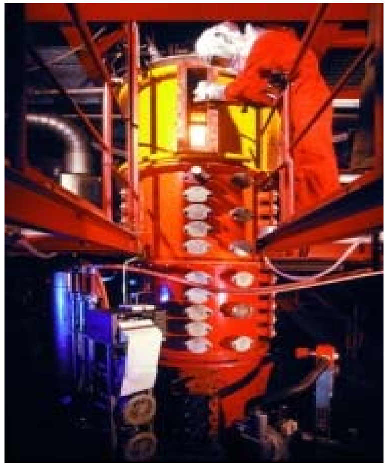
CO_2 emissions in the cement industry



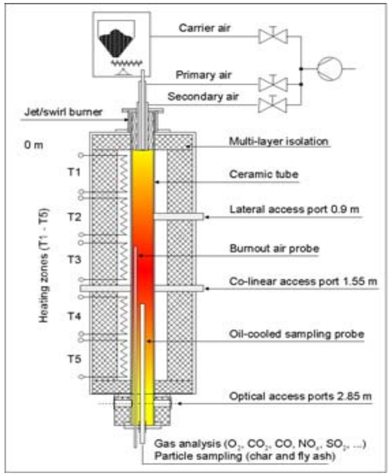
Source: ECRA

CEMCAP Project - technologies to be tested

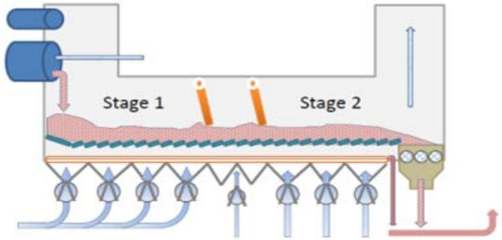
Oxyfuel burner
Existing 500 kWth oxyfuel burner at USTUTT to be modified for CEMCAP



Calciner test rig
Existing <50 kWth entrained flow calciner (USTUTT) to be used for oxyfuel calcination tests



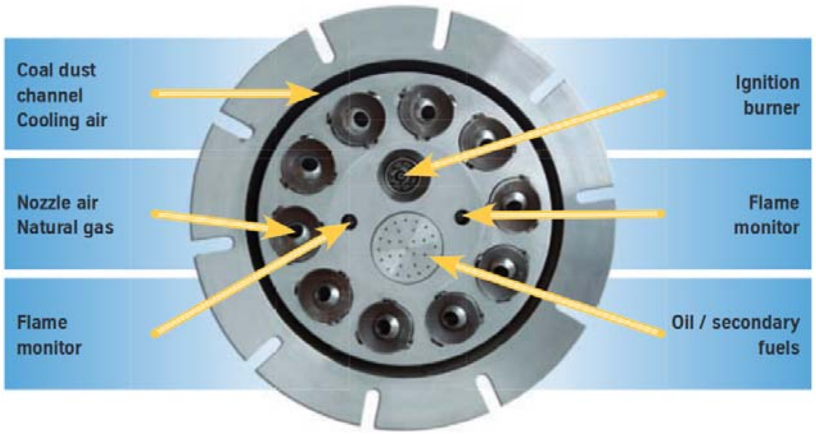
Clinker cooler To be designed and built for on-site testing at HeidelbergCement in Hannover



Source: ECRA

Burner design

a) Design of a prototype oxy-fuel burner for cement kilns.



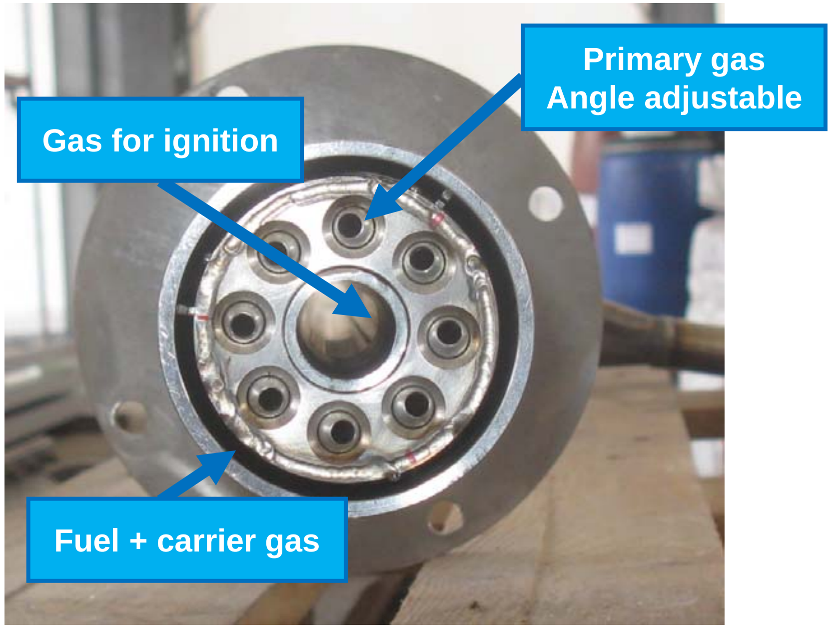
Source: ThyssenKrupp- POLFLAME

Source: ThyssenKrupp

Downscaling criteria

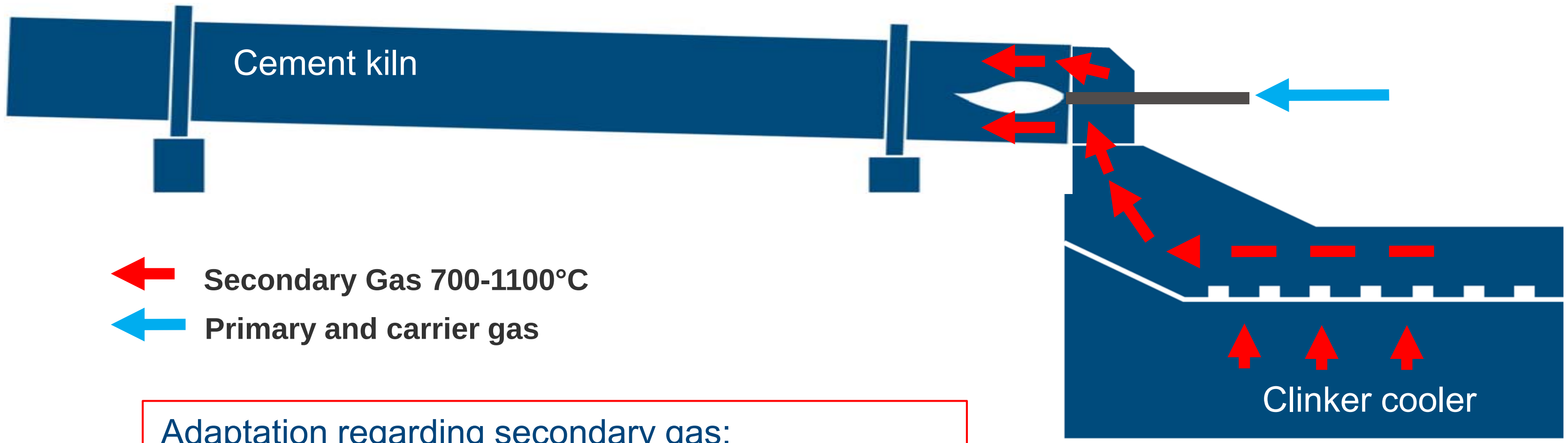
- Flame momentum
- Primary gas velocity (ca. 250 m/s)
- Carrier gas velocity (ca. 15 m/s)
- Swirl angle: 0-40°

Burner prototype manufacture



Adaptation of test facility

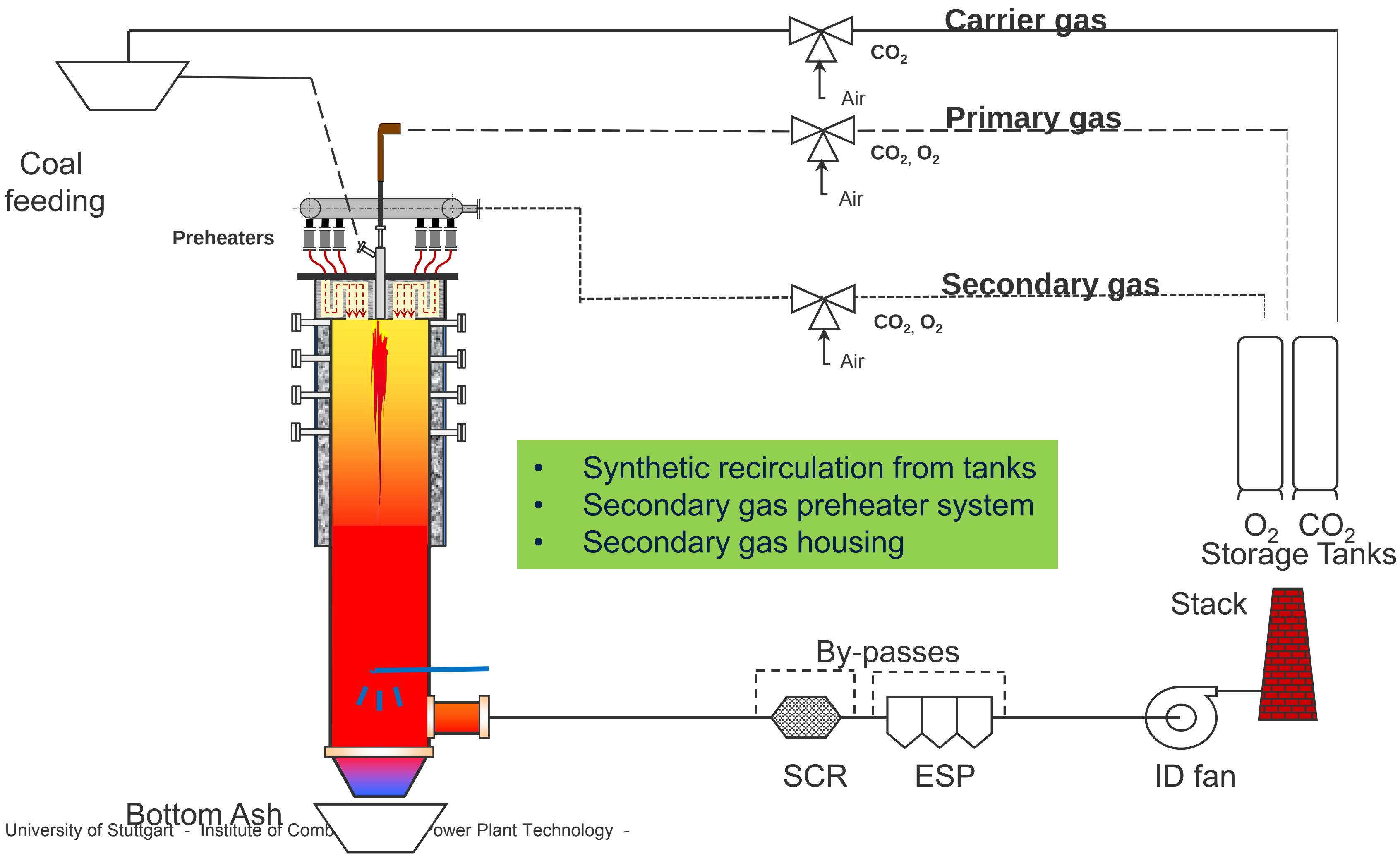
a) Necessary adaptations



Adaptation regarding secondary gas:

- Temperature
- Velocity (5-10 m/s)
- Composition (dry recycling)

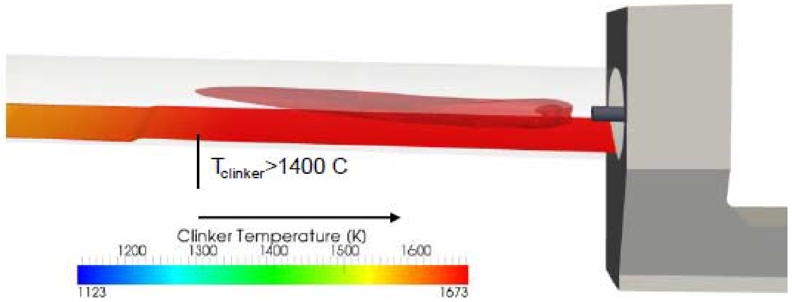
a) Facility adapted for cement conditions



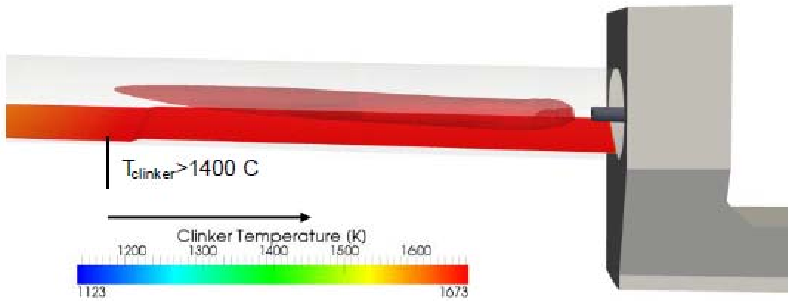
- Synthetic recirculation from tanks
- Secondary gas preheater system
- Secondary gas housing

Previous results published by ECRA:

Reference Case



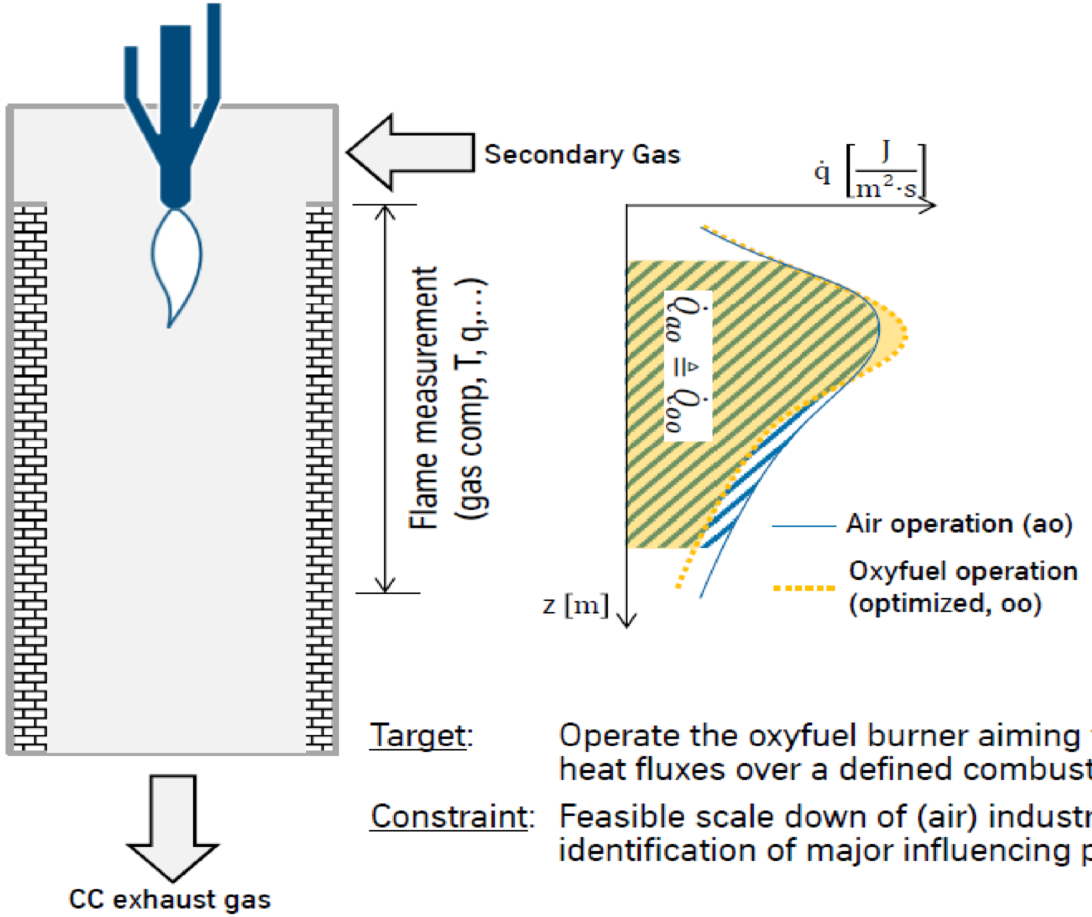
Oxyfuel Case



Source: ECRA CCS Project

- Longer flame.
- Altered temperature profile.
- Altered heat flux profile to material bed.

Proposed validation oxyfuel vs. air operation



Target: Operate the oxyfuel burner aiming to achieve equal heat fluxes over a defined combustion chamber length

Constraint: Feasible scale down of (air) industrial burner, identification of major influencing parameters

Source: ThyssenKrupp

Flame measurements during test campaign

Matrix

	Air	Oxy29*
Primary Gas	67 m^3/h %PA = 15 Air	60 m^3/h %PA = 24 **70% O_2 + 30% CO_2**
Secondary Gas	328 m^3/h 700 °C Air	155 m^3/h 670 °C 21% O_2 + 79% CO_2
Power input	482 kW	482 kW
λ (air-fuel equiv. ratio)	1,09	1,09

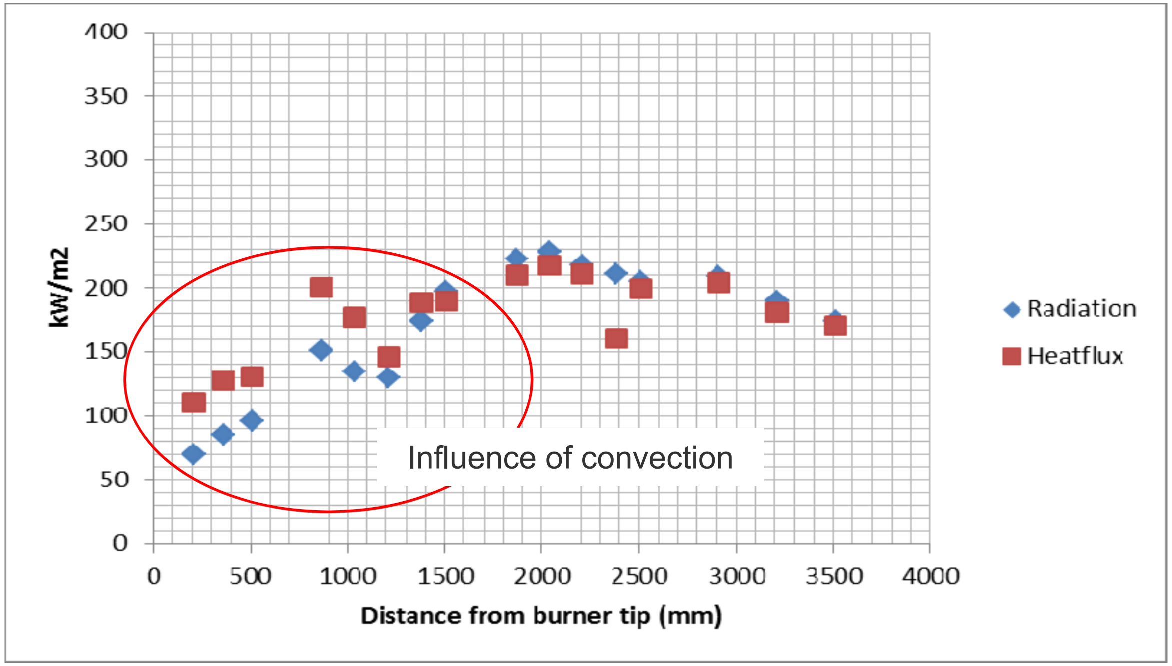
* Oxy29 equivalent to 67% recycle ratio => same adiabatic flame temperature
%PA = Primary air percentage in input combustion gases

Goals:

- Identify differences in heat transfer to the walls during both firing modes.
- Provide experimental data for validation of CFD models.

Gross heat flux measurements

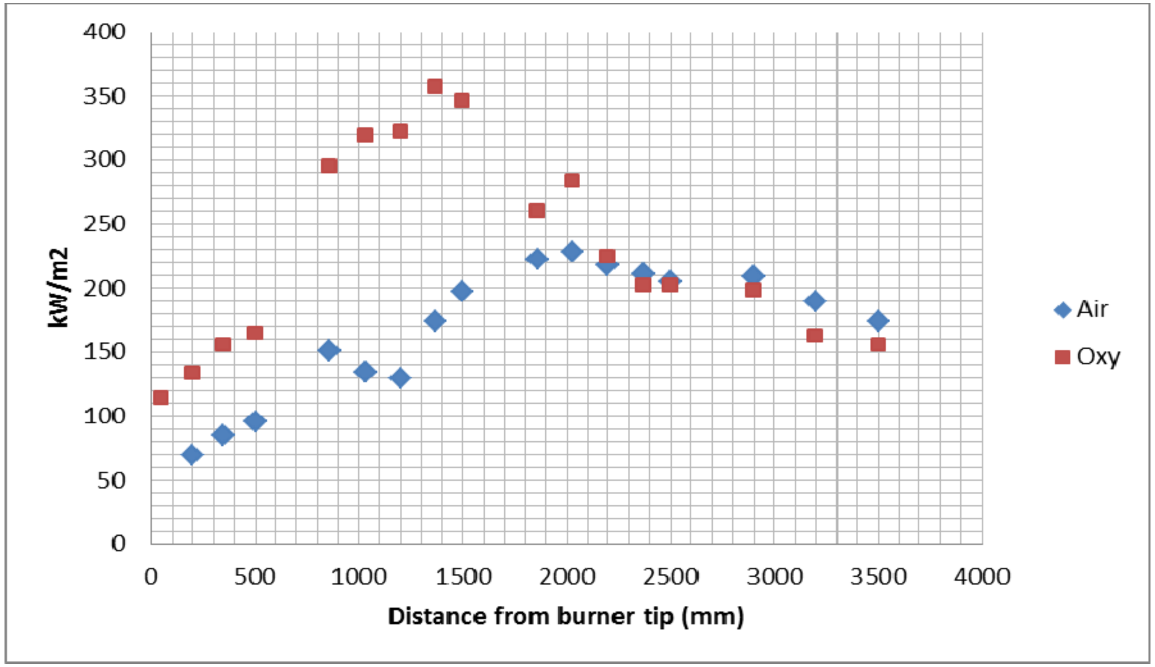
Air case: Radiation vs Total heat flux



Total heat flux = conduction + convection + radiation

Heat flux measurements

Radiative heat flux: Air vs Oxy-fuel



Difference due to:

- Gas radiation
- Particle concentration

Challenges for combustion with petcoke

- Weak flamefront

	Water [%]	Ash [%]	Volatiles [%]	Cfix [%]	C [%]	Htot [%]	H [%]	N [%]	S [%]	Cl [%]
an	4,56	2,12	**11,3**	82,0	77,0	3,91	3,40	1,47	3,03	0,074
wf	-	2,22	**11,9**	85,9	80,7	3,56	3,56	1,57	3,17	0,078

	Air Case	Oxy-fuel
Fuel burnout	98,2	97,4

$$burnout = \frac{1 - \frac{\gamma_{ash,coal}}{\gamma_{ash,sample}}}{1 - \gamma_{ash,coal}}$$

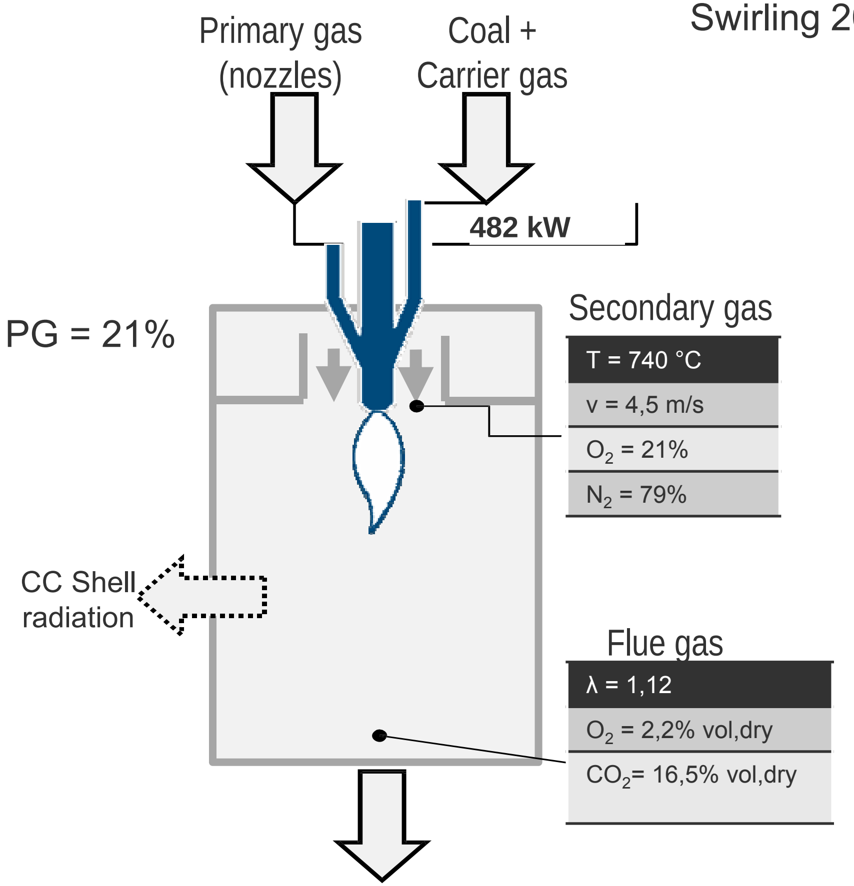
Second experimental campaign:

- Optimized settings: burner position, swirling angle, and primary gas velocity.

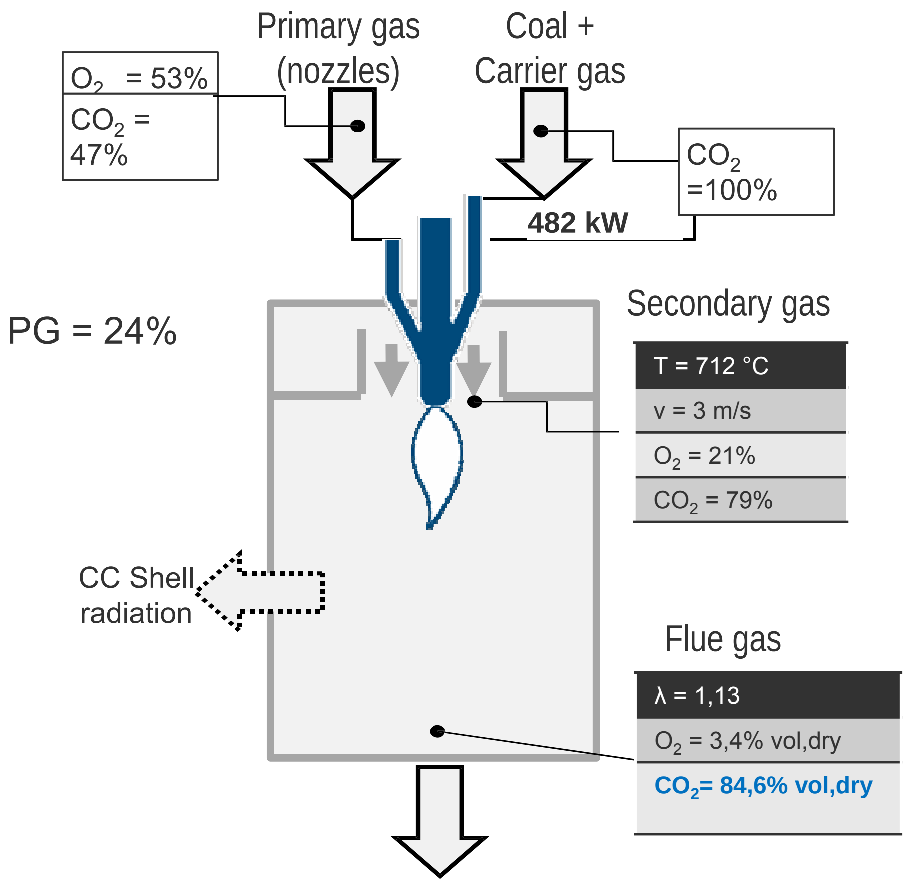
Parameters	Firsts experimental campaign	Second experimental campaign
Fuel	Petcoke	Petcoke
Total O_2 in input gases	29%	27%
Burner position	10 mm inside housing	90 mm outside housing
Swirl angle	40°	20°
Primary gas velocity (approx.)	Air: 117 m/s Oxy-fuel: 108 m/s	Air: 190 m/s Oxy-fuel: 150 m/s

AIR CASE

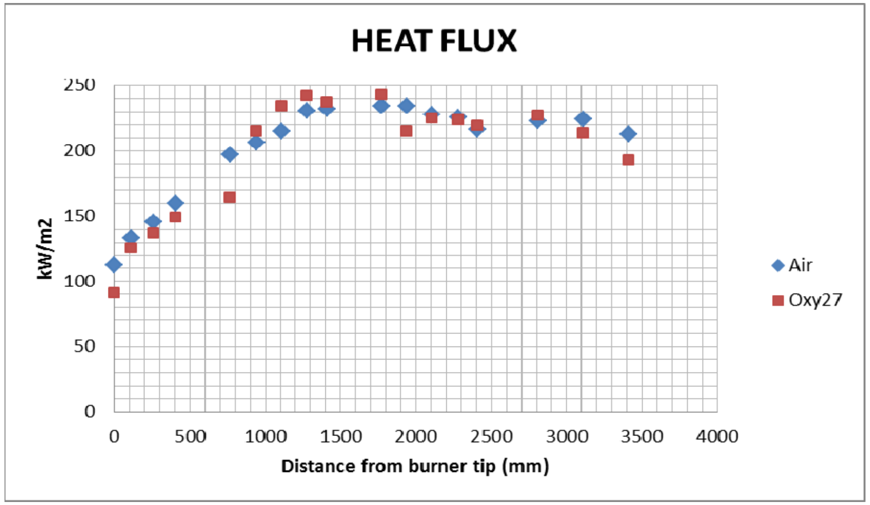
Swirling 20°

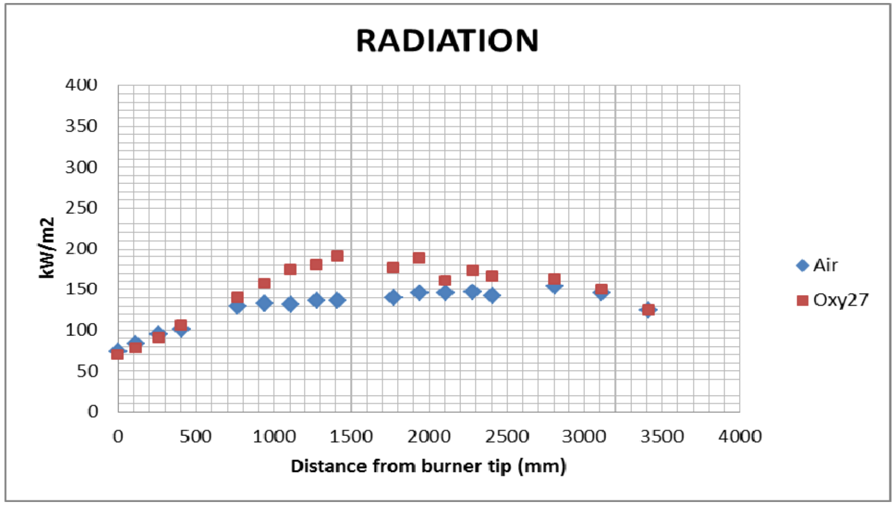


OXY-27



22% less flue gas volume (Nm^3)





	Air Case	Oxy-fuel
Fuel burnout	98,0	98,3

Air combustion

Oxy-fuel combustion

Summary

- Test facility was adapted for relevant oxy-cement tests.
- Burner prototype was designed and tested.
- Demonstration tests evinced suitability to obtain similar radiation profiles under oxy-fuel conditions.

Further Steps

- Additional testing with a higher volatile fuel.
- Simulation of additional oxy-fuel cases not investigated in facility.

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www.sintef.no/cemcap

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Thank you!

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