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CCS in cement industry – Application of the Calcium Looping Technology

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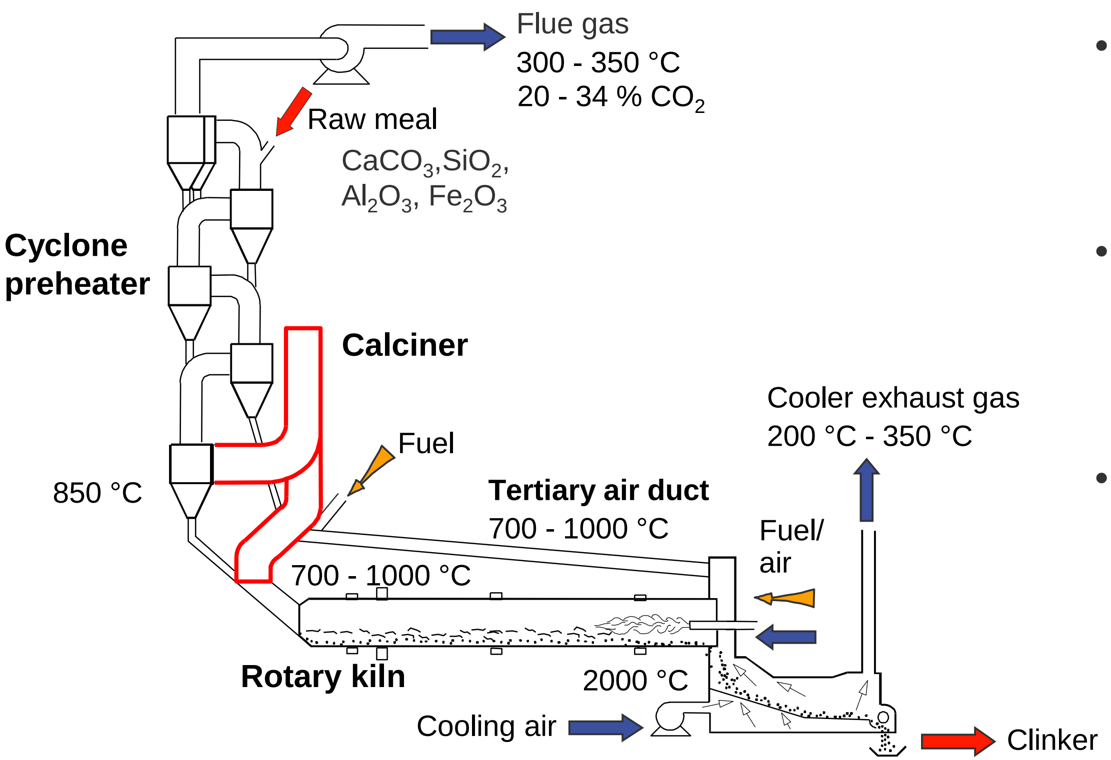
Clinker manufacturing

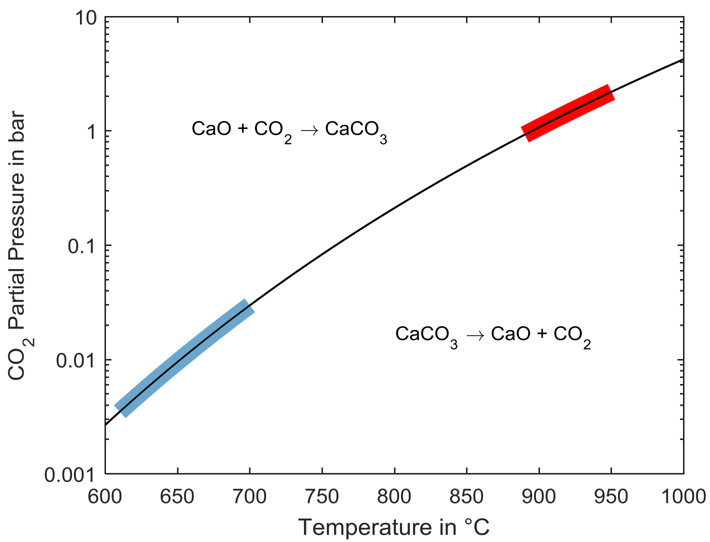


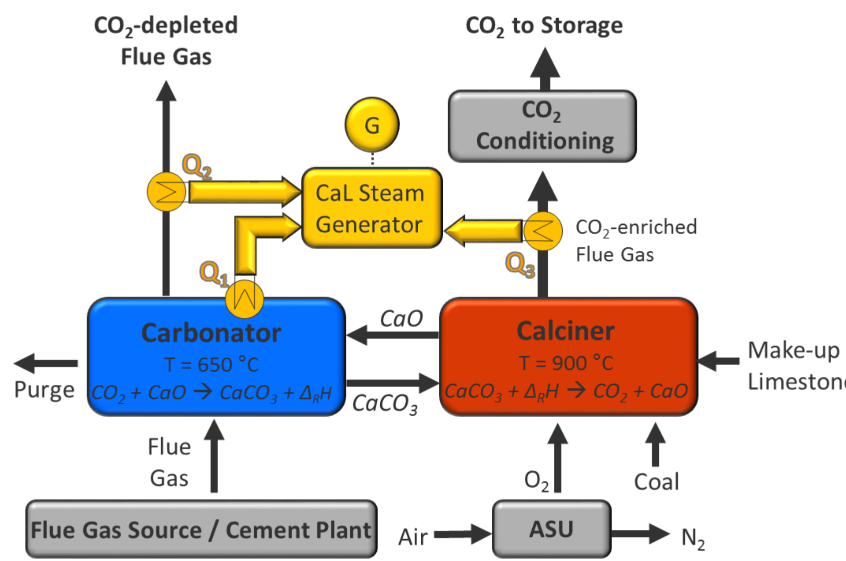
- Cement production constitute ~5 % of global anthropogenic CO_2 emissions
- CO_2 emissions:
  - 60 % by raw materials
  - 40 % by fuel
- Reduction of CO_2 emissions:
  - 56 % CCS
  - 44 % by increase of energy efficiency, alternative fuels, reduction of clinker share

Calcium – Looping

Calcium Looping – General Process Description

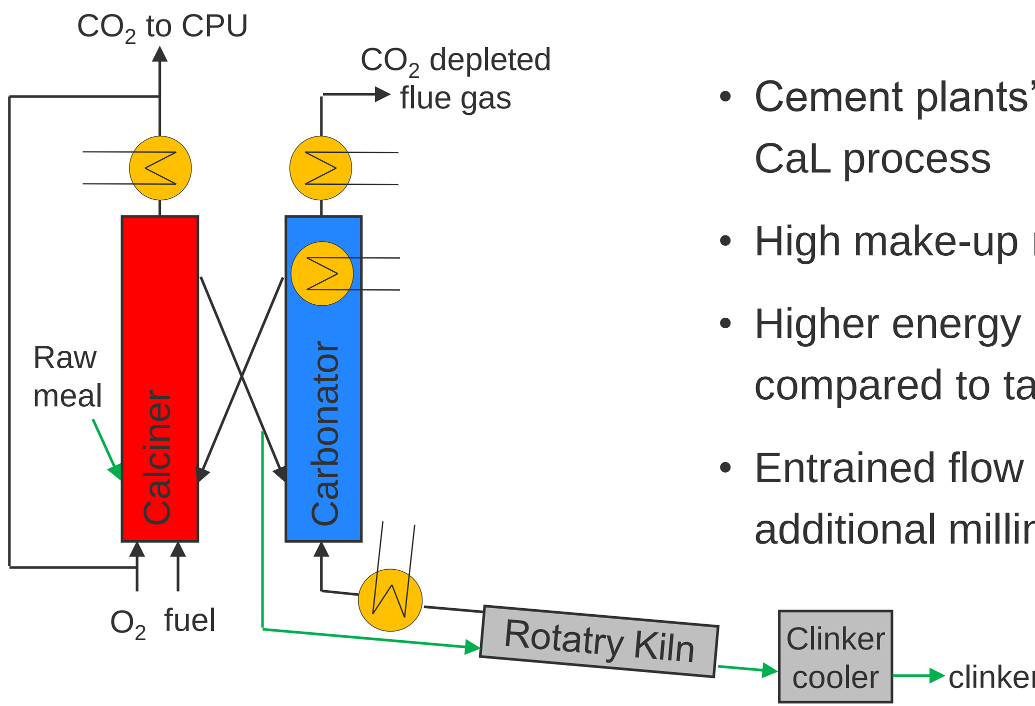
- CO_2 capture by cyclic calcination and carbonation of Calciumcarbonat ($CaCO_3$)
- High energy efficiency due to high temperature level





Calcium Looping – Cement Plant Integration

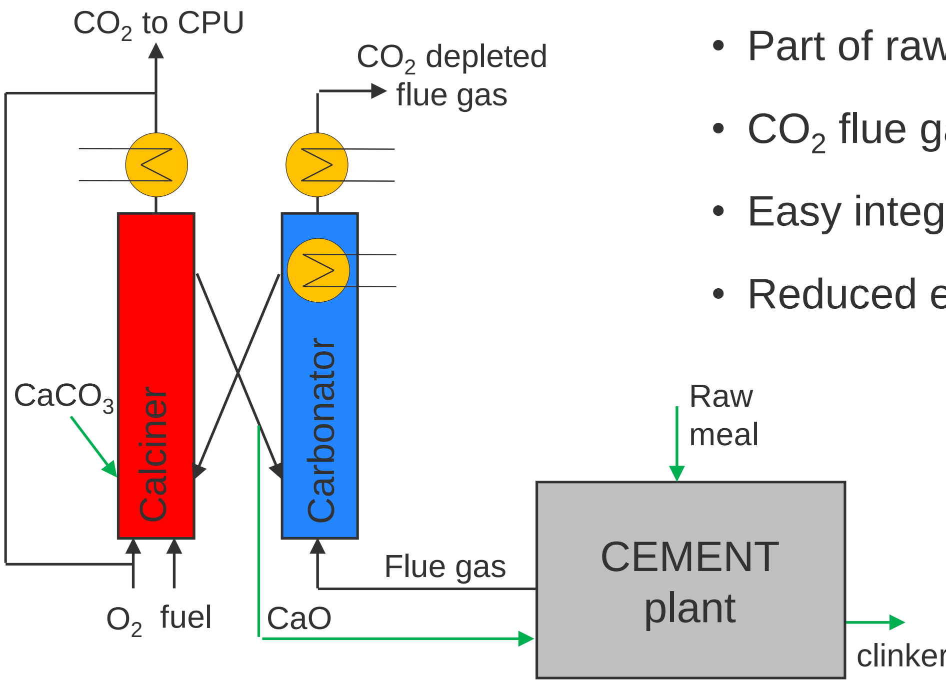
Integrated CaL



- Cement plants' raw meal completely calcined by CaL process
- High make-up ratio realizable
- Higher energy efficiency and higher complexity compared to tail-end
- Entrained flow reactors or CFB reactors with additional milling step if necessary

Calcium Looping – Cement Plant Integration

Tail-end CaL



- Part of raw meal calcined in CaL process
- CO_2 flue gas concentration ~ 20 - 35 %
- Easy integration
- Reduced energy efficiency

Results

Experimental results – Experimental facility

200 – 230 kW_{th} pilot scale facility (3 reactors)

Bubbling bed reactor (1x)

- diameter: 330 mm
- height: 6 m

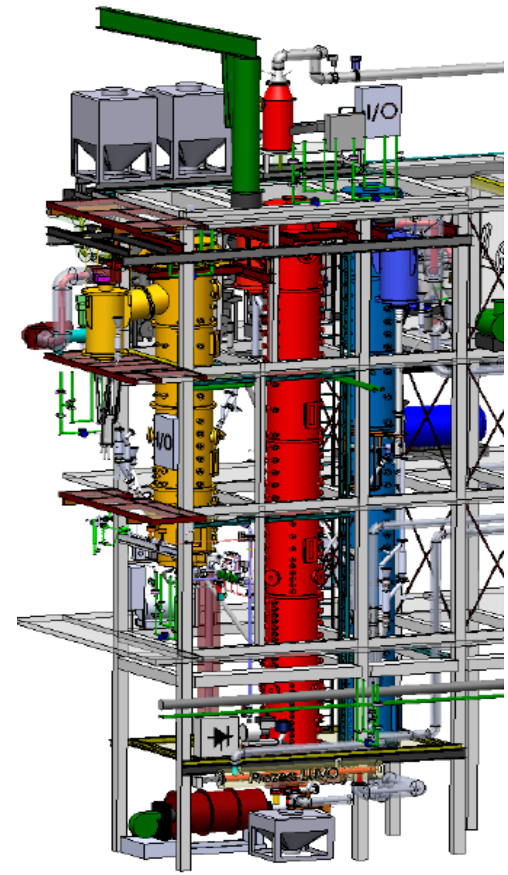
Circulating fluidized bed reactor (2x)

- diameter: 200 mm
- height: 10 m

Possible reactor configuration: CFB-CFB, BFB-CFB

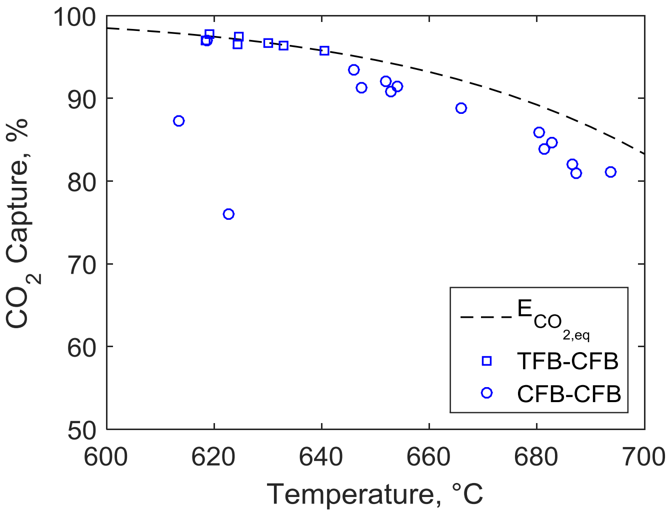
No electrical heating (heated by combustion)

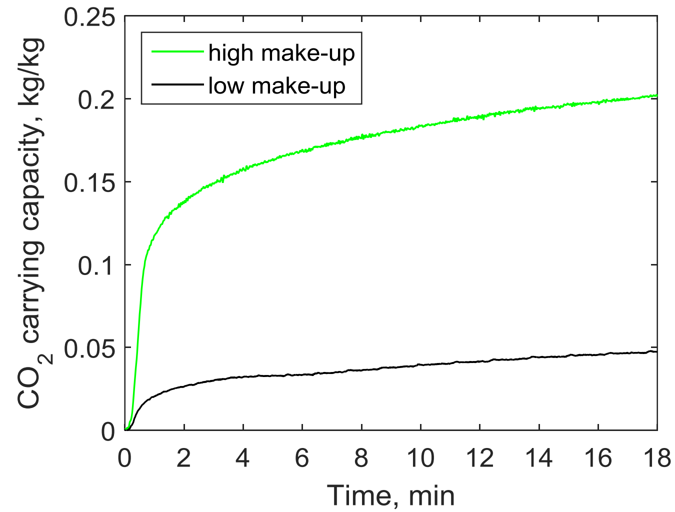
Gas analysis (H_2, CO, CH_4, O_2, CO_2, C_xH_y, SO_2, NO_X)



Experimental results – CO_2 capture

- CO_2 capture was limited by the equilibrium CO_2 capture
- High CO_2 capture rate above 90 % reached
- High sorbent activity due to high make-up flows





Simulation results*

*Spinelli et al. **Integration of Ca-Looping systems for CO_2 capture in cement plants, Energy Proceedia (GHGT-13)**

	Reference cement plant w/o CO_2 capture	tail-end CaL configuration	integrated CaL configuration
Integration level [%]	--	20	100
F_0/F_{CO2}	--	0.16	4.1
F_{Ca}/F_{CO2}	--	4.8	4.0
Carbonator CO_2 capture efficiency [%]	--	88.8	80.0
Total fuel consumption [MJ_{LHV}/t_{clk}]	3223	8672	4740
Rotary kiln burner fuel consumption [MJ_{LHV}/t_{clk}]	1224	1210	1180
Pre-calciner fuel consumption [MJ_{LHV}/t_{clk}]	1999	1542	3560
CaL calciner fuel consumption [MJ_{LHV}/t_{clk}]	--	5920	
Electric balance [kWh_{el}/ t_{clk}]			
Gross electricity production	--	579	163
ASU consumption	--	-117	-73
CO_2 compression	--	-146	-111
Carbonator and calciner fans	--	-25	-11
Cement plant auxiliaries	-132	-132	-132
Net electric production	**-132**	**159**	-164

Simulation results*

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	Reference cement plant w/o CO_2 capture	tail-end CaL configuration	integrated CaL configuration
Direct CO_2 emissions [kg_{CO2}/t_{clk}]	863.1	143.2	71.4
Indirect CO_2 emissions [kg_{CO2}/t_{clk}]	105.2	-123.5	128.7
Equivalent CO_2 emissions [kg_{CO2}/t_{clk}]	968.3	19.7	200.1
Equivalent CO_2 avoided [%]	--	98.0	79.3
SPECCA [MJ_{LHV}/kg_{CO2}]	--	3.26	2.32

$$SPECCA = \frac{q_{equivalent} - q_{equivalent,ref}}{e_{CO2,equivalent,ref} - e_{CO2,equivalent}}$$

Conclusion

Conclusion and Outlook

CaL CO_2 capture:

- Beneficial Calcium Looping operation conditions due to reutilization of sorbent in cement plant
- High CO_2 capture rate >90 % CO_2 capture achieved over a wide range of parameters

Tail-end CaL configuration:

- easy to integrated
- CFB reactors → minor technical uncertainties
- Significant increase of fuel input (+270 %)
- Electric power export and very low equivalent emissions

Integrated CaL configuration:

- Complex integration
- Moderate increase of fuel input (+47 %)
- Electric consumption similar to reference cement plant
- Research upon raw meal sorbent performance and entrained flow carbonator sizing

Thank you for your attention!

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Thank you!

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