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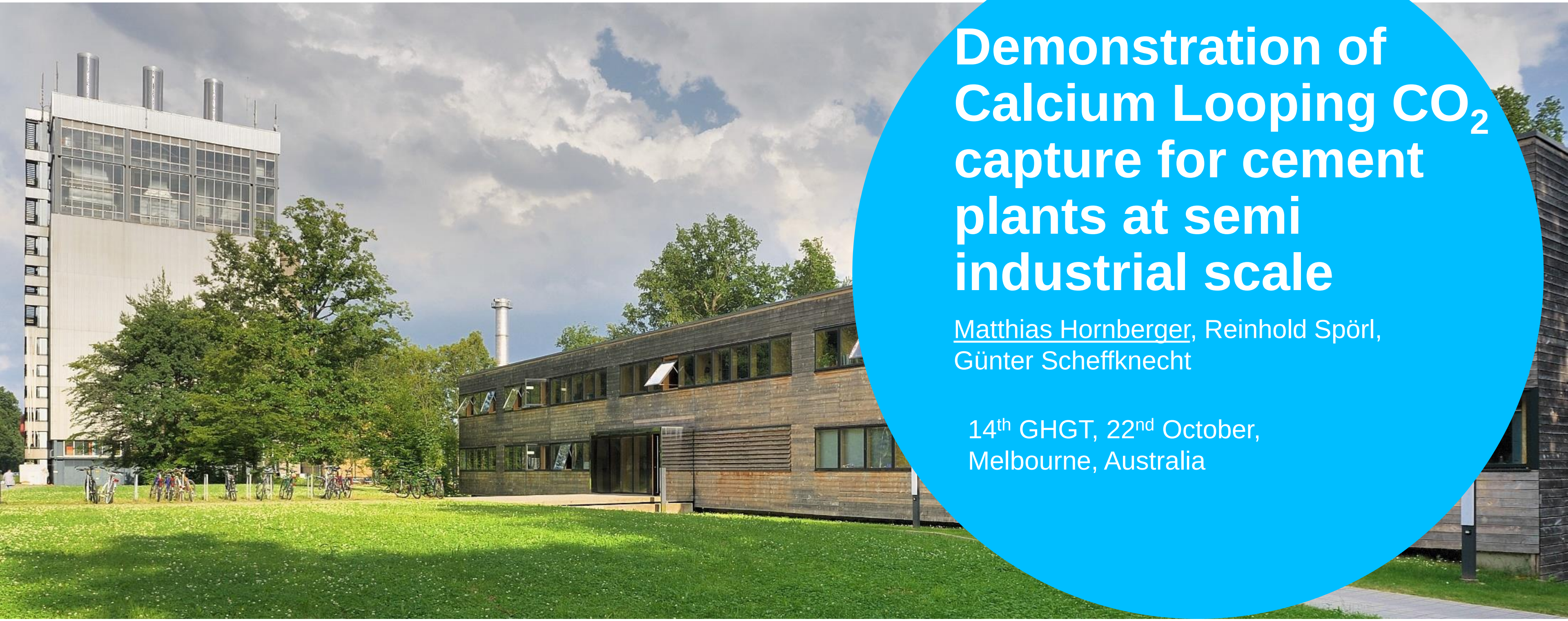

Demonstration of Calcium Looping CO_2 capture for cement plants at semi industrial scale

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14th GHGT, 22nd October, Melbourne, Australia

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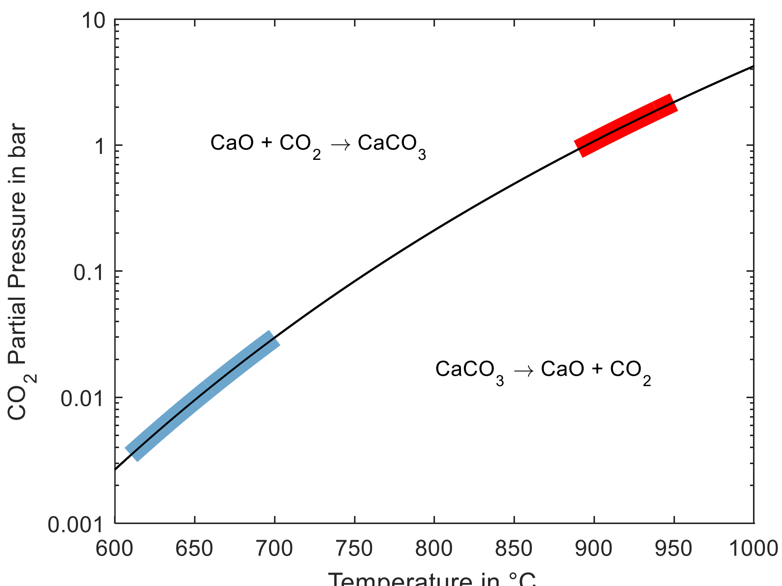
Fundamentals of Calcium Looping CO_2 capture from cement plants

Calcium Looping CO_2 capture

$$CaCO_3 \rightleftharpoons CaO + CO_2 \qquad \Delta_R H = +178.2 \frac{kJ}{mol}$$

Calcination-carbonation equilibrium calculated by



- Solid sorbent cycle process
- CO_2 capture by cyclic calcination and carbonation of $CaCO_3$/CaO
- Efficient energy recuperation because of high temperature level

Calcium Looping CO_2 capture process

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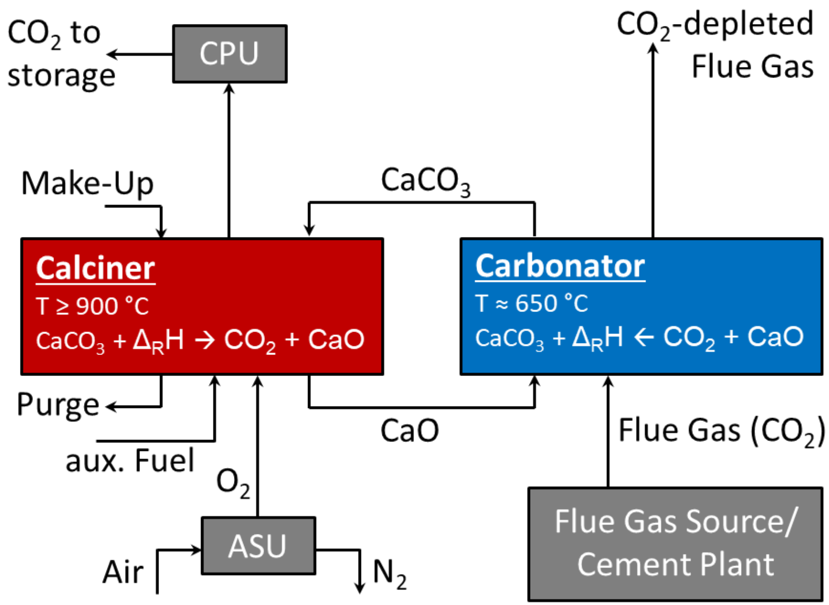

Definitions

- Sorbent activity: $X_{avg} = \frac{M_{CO_2}}{M_{Sorbent}}$
- Make-Up ratio: $\frac{\dot{N}_{CaO,fresh}}{\dot{N}_{CO_2,Carb,in}}$
- Looping ratio: $\frac{\dot{N}_{CaO,trans}}{\dot{N}_{CO_2,Carb,in}}$

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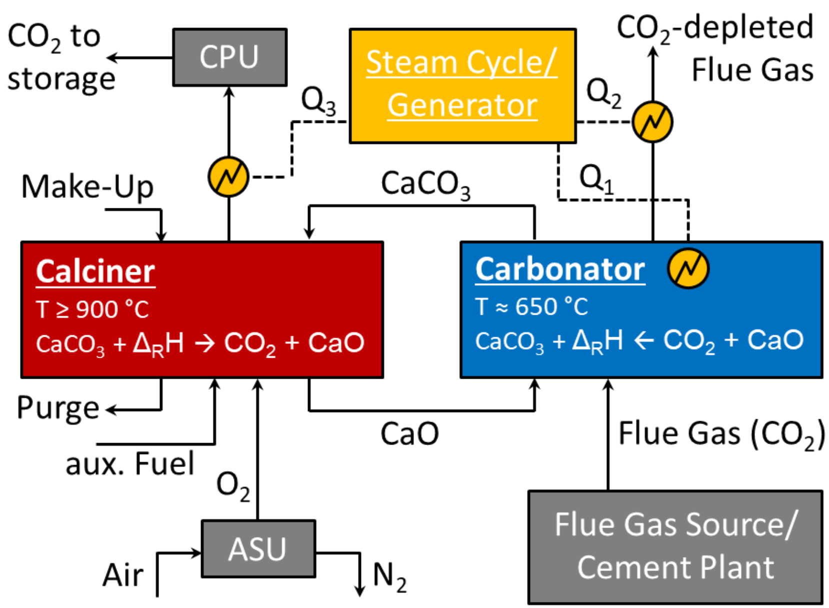

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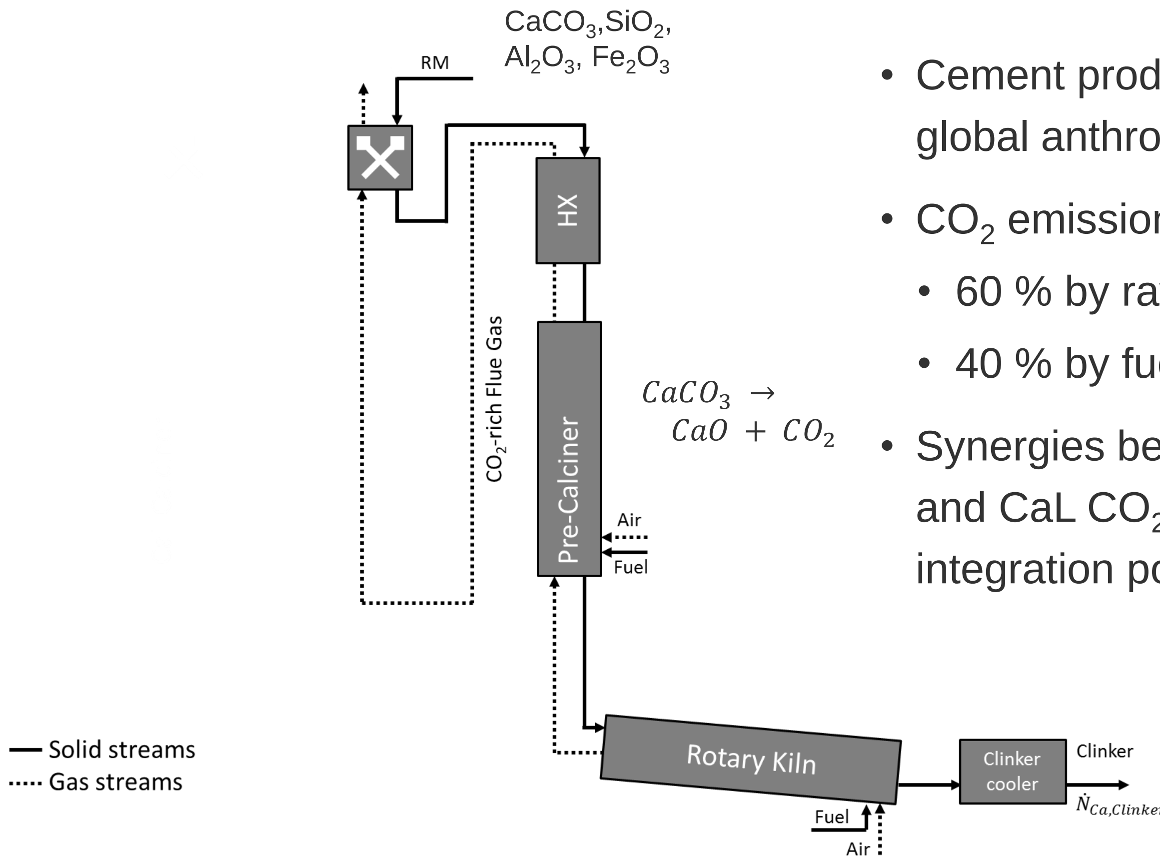
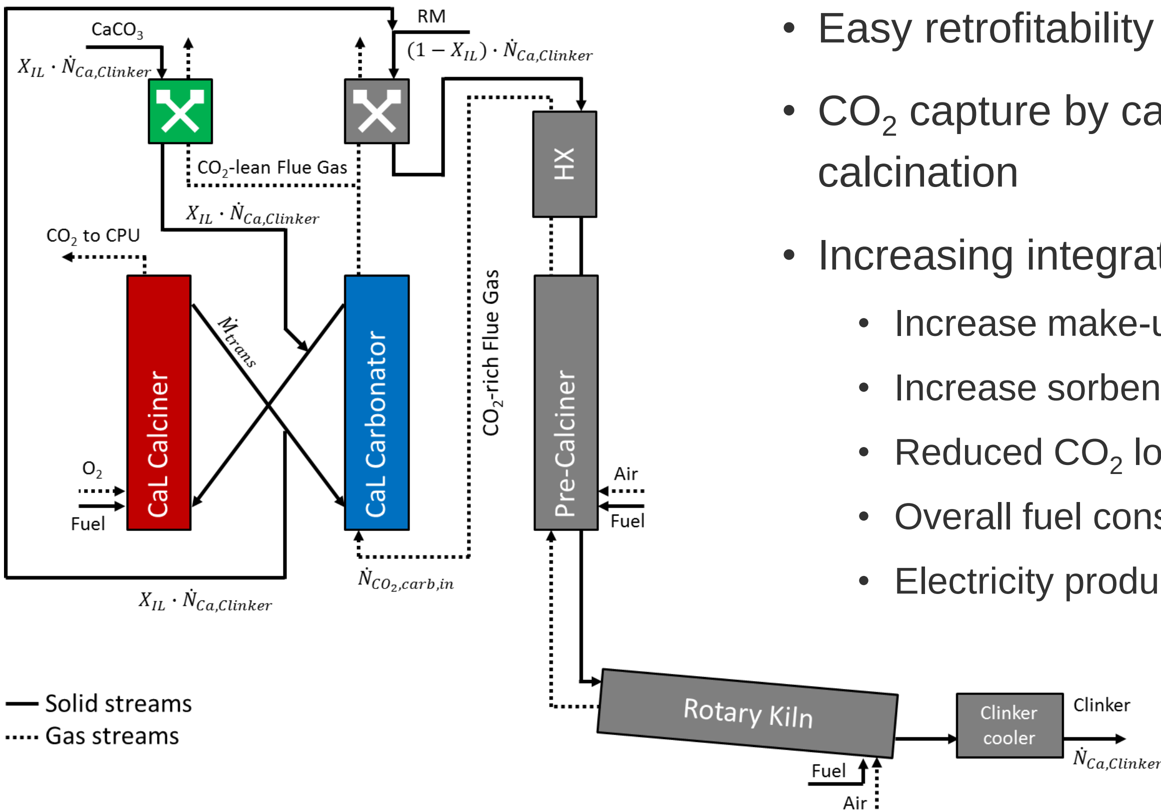
Clinker manufacturing process



- Cement production constitute ~5-8 % of global anthropogenic CO_2 emissions
- CO_2 emissions:
  - 60 % by raw materials
  - 40 % by fuel
- Synergies between clinker manufacturing and CaL CO_2 capture by solid and energy integration possible

Tail-end Calcium Looping CO_2 capture from cement plants



- Easy retrofitability
- CO_2 capture by carbonation and oxy-fuel calcination
- Increasing integration level (X_{IL}) leads to:
  - Increase make-up to CaL system
  - Increase sorbent activity
  - Reduced CO_2 load (Cal oxy-fuel calcination)
  - Overall fuel consummation increases
  - Electricity production (CO_2 neutral)

$$X_{IL} = \frac{\dot{N}_{CaO,CaL}}{\dot{N}_{CaO,Clinker}}$$

Methodology / experimental set-up

Fluidized Bed Research Facilities – MAGNUS

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

Bubbling bed reactor (1x)

- diameter: 330 mm
- height: 6 m

Circulating fluidized bed reactor (2x)

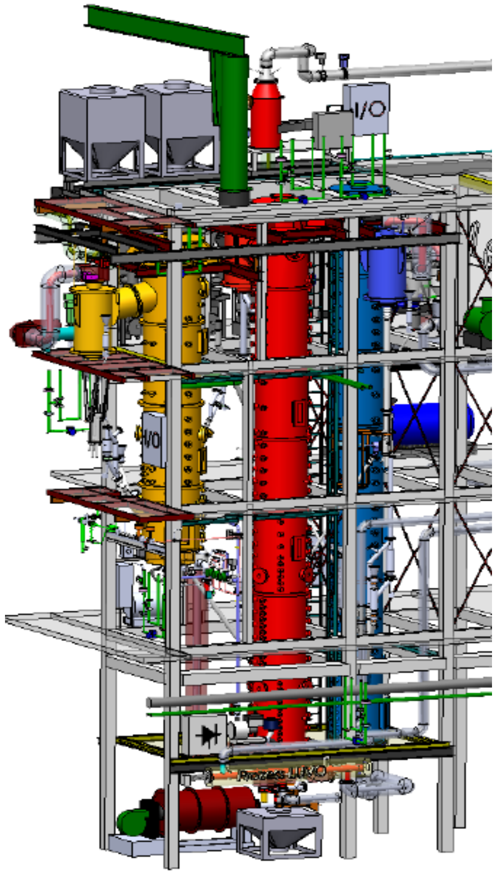
- diameter: 200 mm
- height: 10 m

Possible reactor configuration: CFB-CFB, BFB-CFB

Hot flue gas recirculation for oxy-fuel combustion

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

No electrical heating (heated by combustion)



Experimental conditions

- CO_2 flue gas concentration: 15 – 33 vol%
- Volume Flow: up to 180 Nm_3/h (~ 0.1 % of cement plant flue gas)
- Make-up flow/ratio: up to 50 kg/h / 1 mol_{CaO}/mol_{CO2} ;

Limestone	CaO	MgO	SiO_2	Al_2O_3	Others	CO_2
	wt%, wf	wt%, wf	wt%, wf	wt%, wf	wt%, wf	wt%, wf
Western Germany	54.5	0.7	0.4	1.2	0.2	43.0

*determined by TIC

Coal	C	H	O*	N	S	Ash	H_2O	H_i
	wt%, waf	wt%, waf	wt%, waf	wt%, waf	wt%, waf	wt%, wf	wt%, ad	MJ/kg, wf
Columbian I	80.3	4.9	12.3	1.9	0.6	9.6	7.4	28.98
Columbian II	77.6	5.3	14.4	1.6	1.1	9.13	7.4	28.09

*calculated by difference

wf: water free;
waf: water and ash free;
ad: air dried

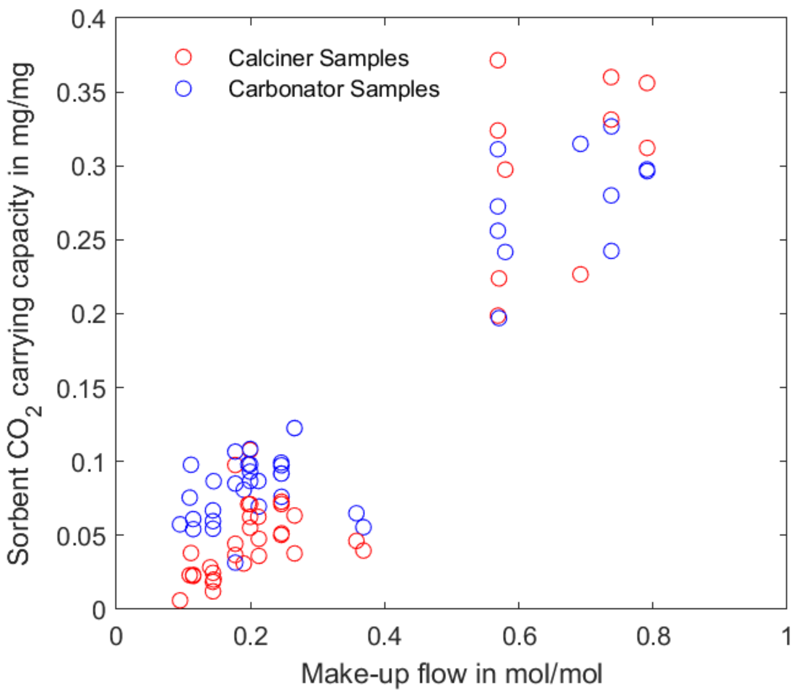
Results and discussion

Results and discussion – Sorbent CO_2 carrying

- Sorbent capacity depends strongly on make-up ratio (“sorbent age”)
- At lower make-up ratios sorbent activity of carbonator samples significantly higher than calciner samples
- Hydration during cooling of samples higher for carbonator samples

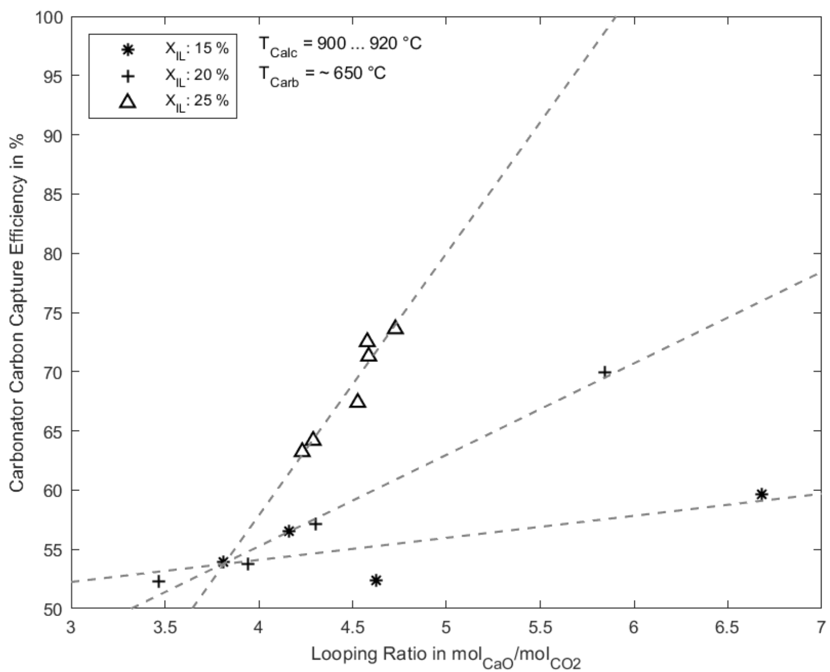
➡ indicates structural during carbonation

Average sorbent capacity of carbonator and calciner samples taken during the experimental campaigns



Results and discussion – CO_2 capture performance

Carbonator CO_2 capture efficiency vs looping ratio at lower integration levels

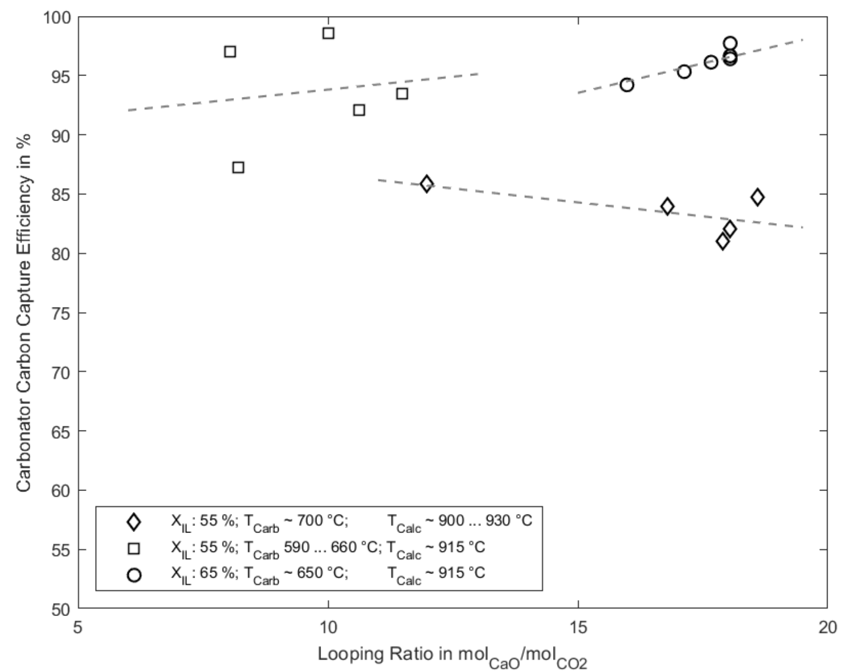


- Higher CO_2 concentration at lower integration levels leads to reduced looping ratios
- Limitation of CO_2 capture by incoming amount of (active) CaO
  - ➡ CO_2 capture increases with looping ratio
  - ➡ Stronger improvement of CO_2 capture with looping ratio at higher integration level

Results and discussion – CO_2 capture performance

- CO_2 capture up to 98 % achieved due to high sorbent activity
- Limitation of CO_2 capture by calcination-carbonation equilibrium at higher integration levels
- No influence on CO_2 capture efficiency at higher integration levels (i.e. make-up ratios)

Carbonator CO_2 capture efficiency vs looping ratio at enhanced integration levels



Conclusion

Conclusion

- Synergies between clinker manufacturing and Calcium Looping CO_2 capture due to use of common feedstock ($CaCO_3$)
- Different integration levels (15 % to 65 %) for a tail-end Calcium Looping cement plant system has been assessed
- Calcium Looping CO_2 capture for cement application has been investigated at IKF‘s 200 kW_{th} Calcium Lopping pilot plant achieving CO_2 capture efficiencies up to 98 %
- Sorbent’s CO_2 carrying capacity improves with increasing integration level (i.e. make-up)
- For lower integration levels a significant improvement of CO_2 capture with increasing looping ratio was found, while for higher integration levels the CO_2 capture was limited by the carbonation equilibrium

Thank you for your attention!

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Thank you!

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