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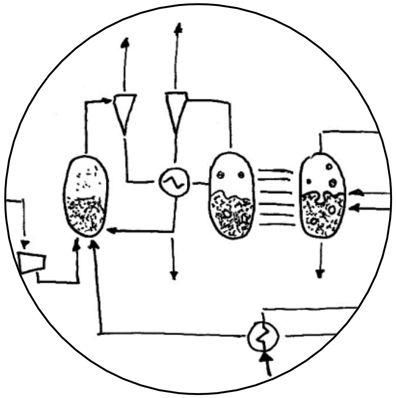
Integration of the IHCaL Process into Lime Plants

ANICA Virtual Workshop
October 6, 2020

Martin N. Greco-Coppi

Outline



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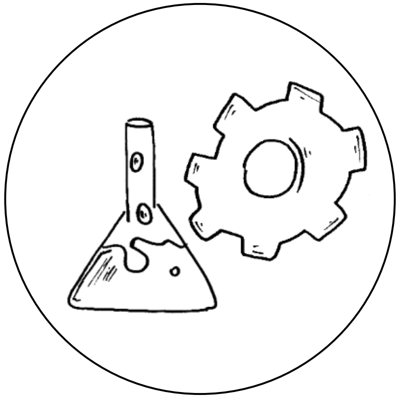

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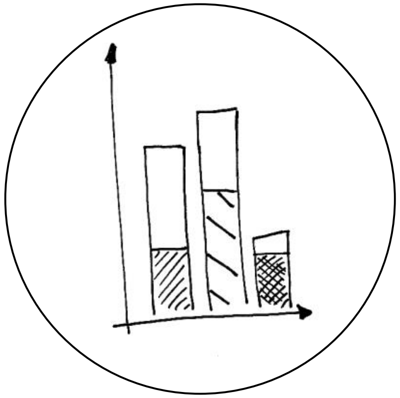

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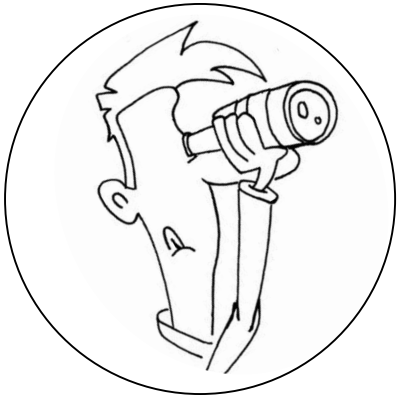

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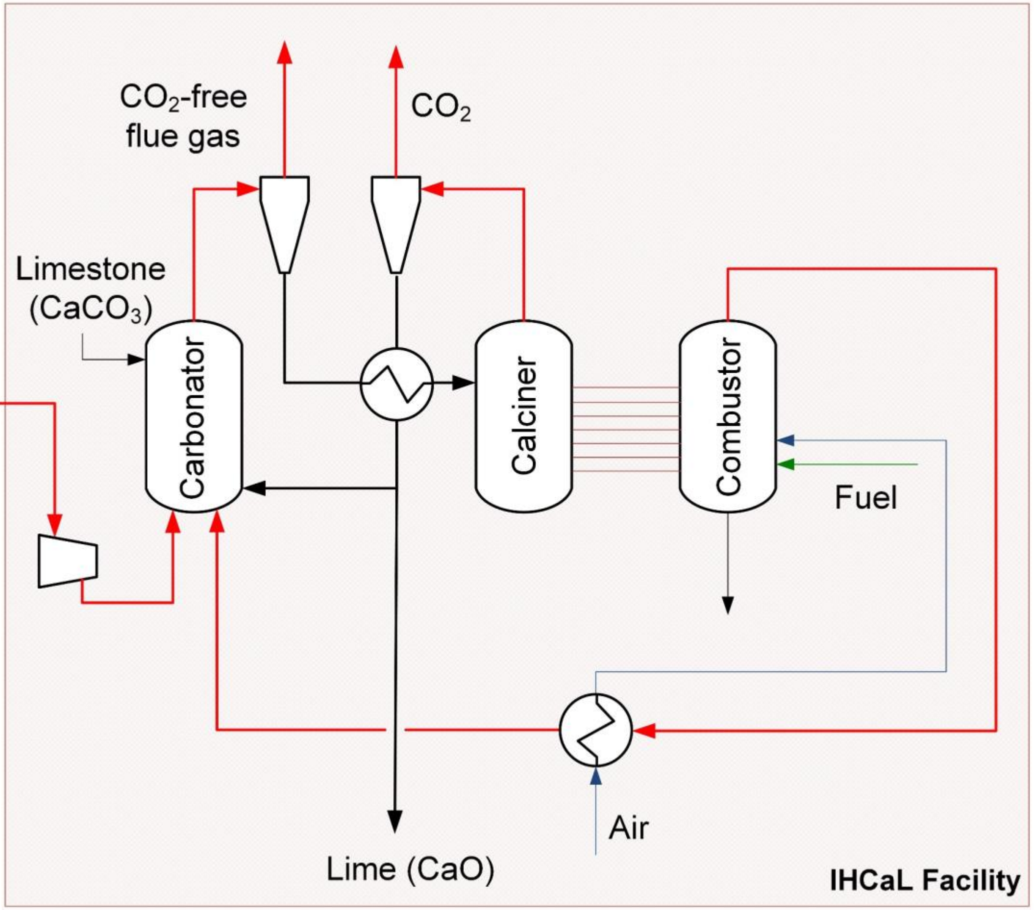
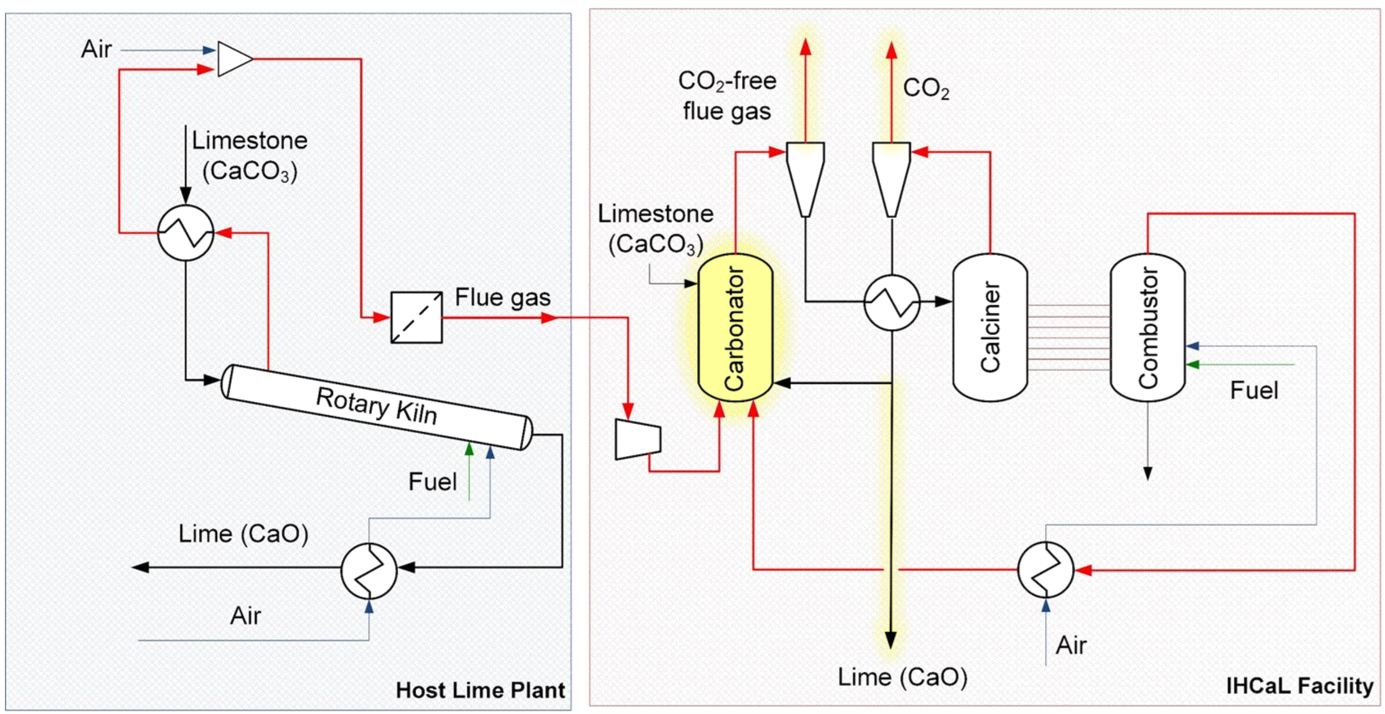


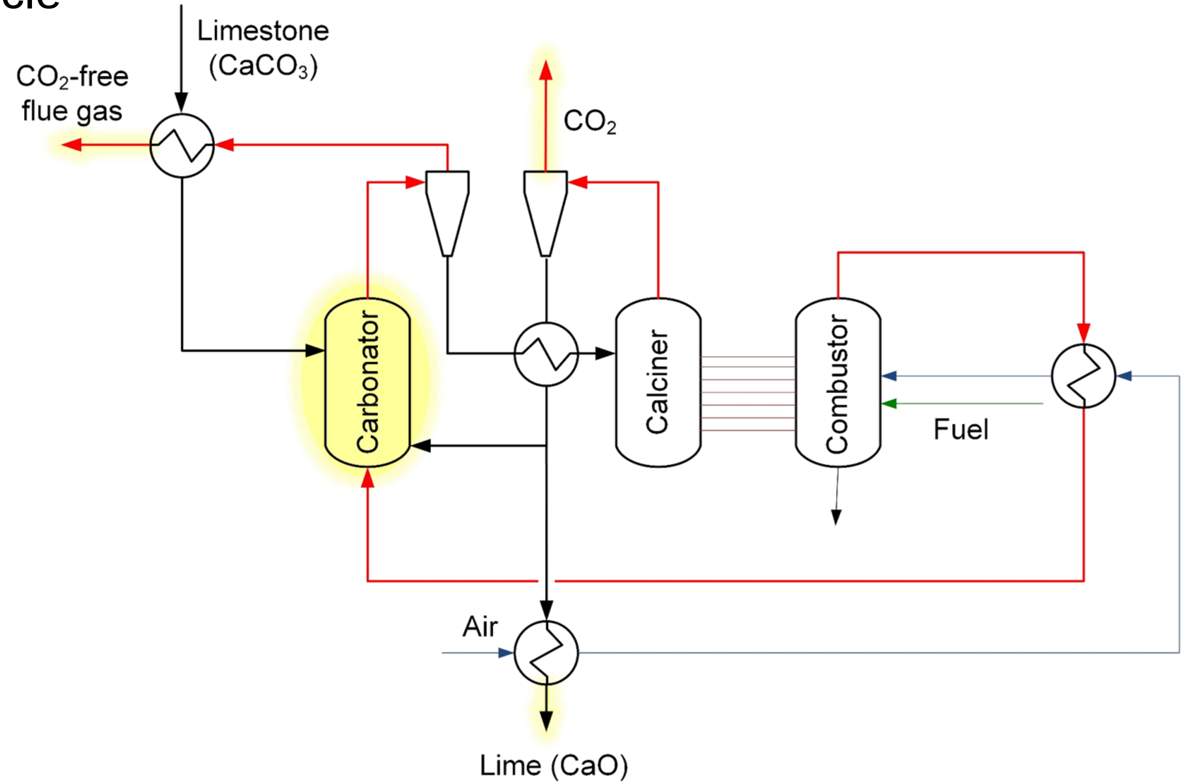
CO2-free flue gas
CO2
Limestone (CaCO3)
Carbonator
Calciner
Combustor
Fuel
Air
Lime (CaO)
IHCaL Facility

- IHCaL facility located downstream of lime kiln
- Suitable for retrofitting
- Heat utilization: steam cycle



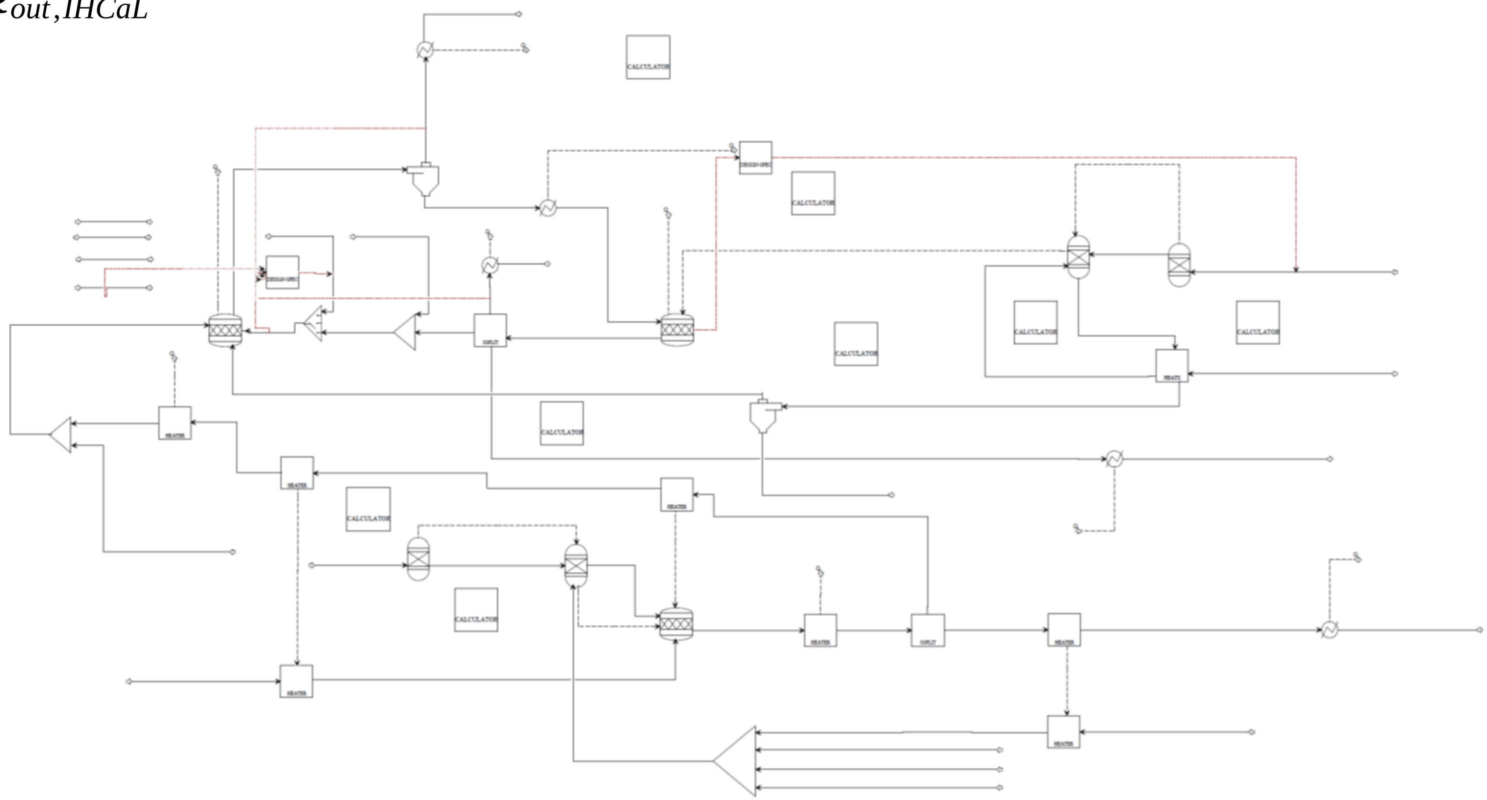
Integration Concepts
Fully Integrated

- Completely new facility: high integration
- Lime calcined by indirectly heating
- Mass integration
- Heat utilization: steam cycle



Methodology
Process Modelling

- Aspen Plus software
- Base case → heat and mass balances
- Sensitivity analysis → operation parameters
- $P_{el} = 0.45 \cdot \dot{Q}_{out,IHCaL}$

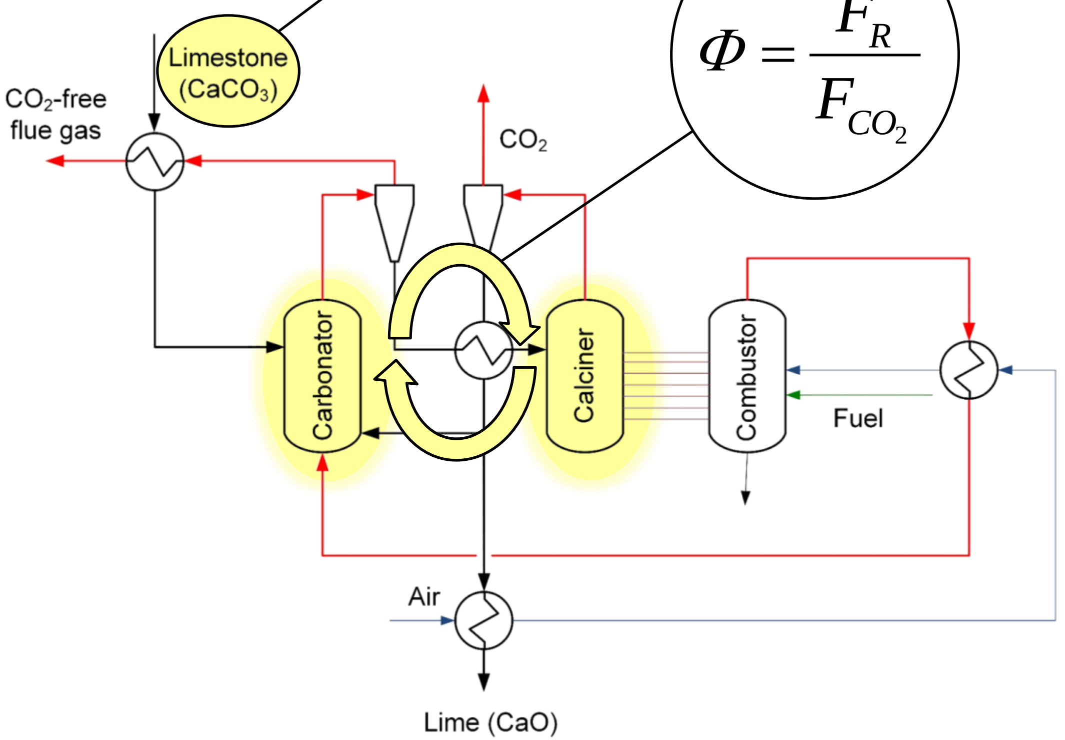


Methodology
Main Process Parameters

- Specific make-up ratio (Λ):
- Specific circulation rate (Φ):
- Conversion factors (f_{carb}; f_{calc})

$$\Lambda = \frac{F_0}{F_{CO_2}}$$

$$\Phi = \frac{F_R}{F_{CO_2}}$$



Sources:
Haaf M. *Utilization of Waste-derived Fuels in Calcium Looping Process*. TU Darmstadt; 2020.
Junk M., et. Al. *Technical and Economical Assessment of the Indirectly Heated Carbonate Looping Process*. Journal of Energy Resources Technology; 2016.

- CO_2 capture efficiency:

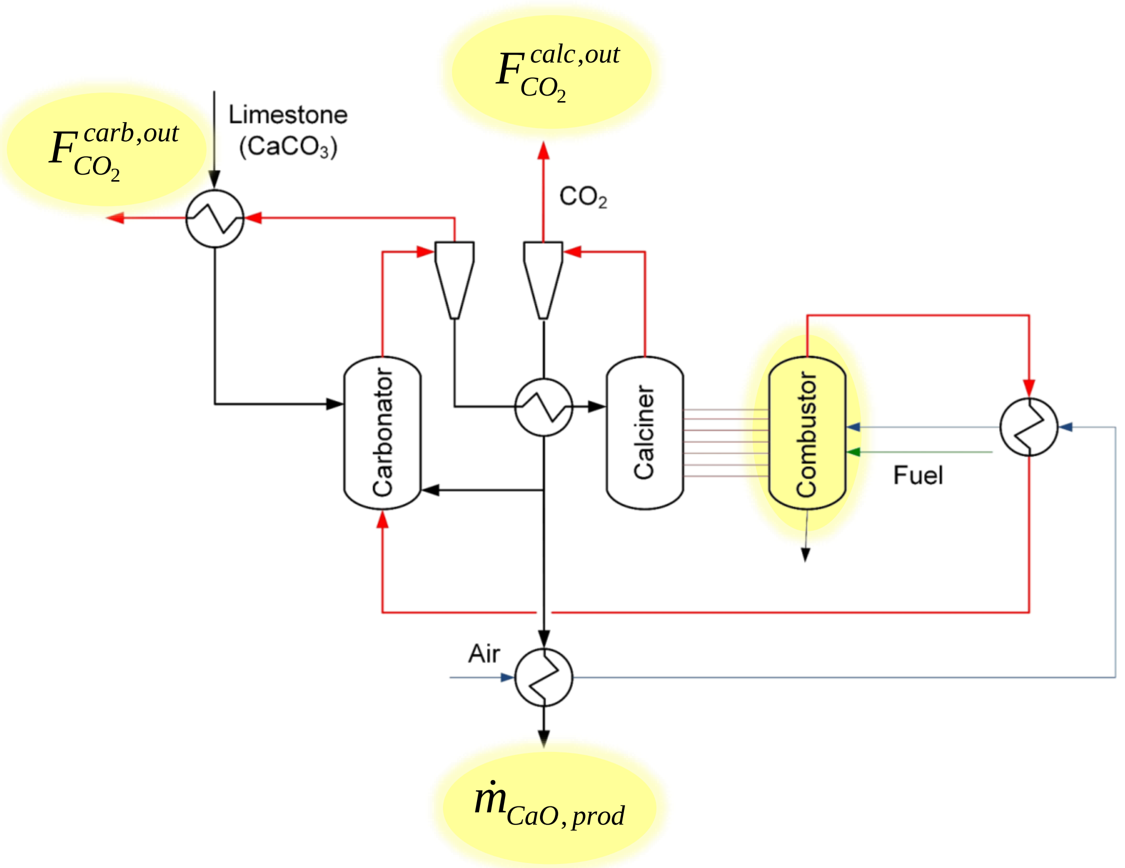
$$E = \frac{F_{CO_2}^{calc,out}}{F_{CO_2}^{calc,out} + F_{CO_2}^{carb,out}}$$

- Product ratio:

$$PR = \frac{\dot{m}_{CaO,prod}}{\dot{m}_{CaO,prod}^{ref}}$$

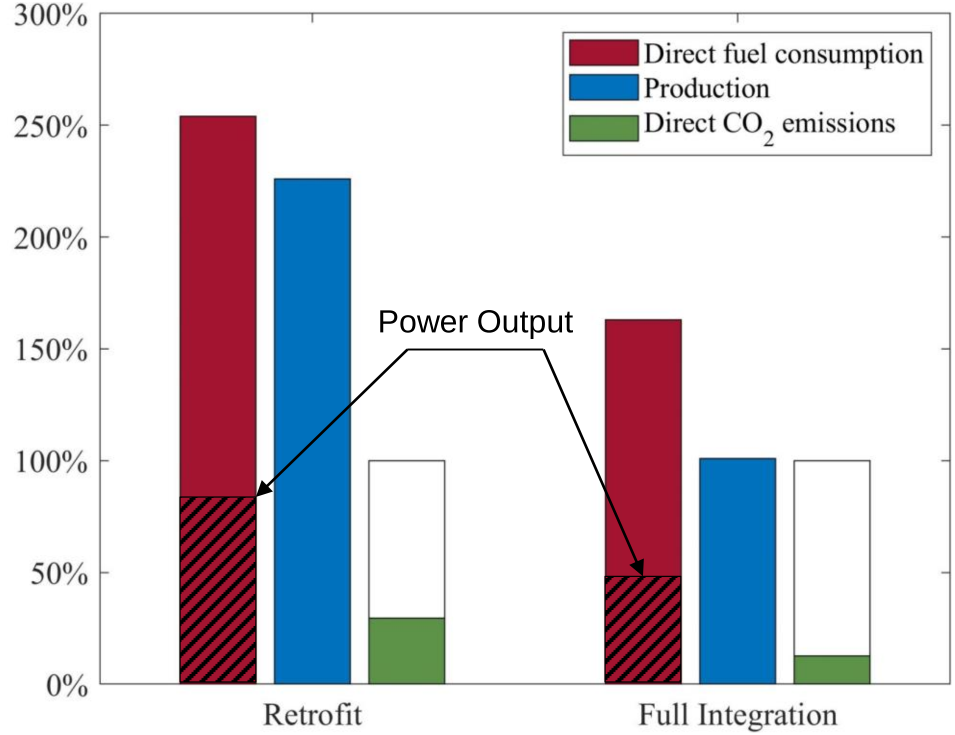
- Heat ratio:

$$HR = \frac{\dot{Q}_{in} / \dot{m}_{CaO,prod}}{\dot{Q}_{in}^{ref} / \dot{m}_{CaO,prod}^{ref}}$$

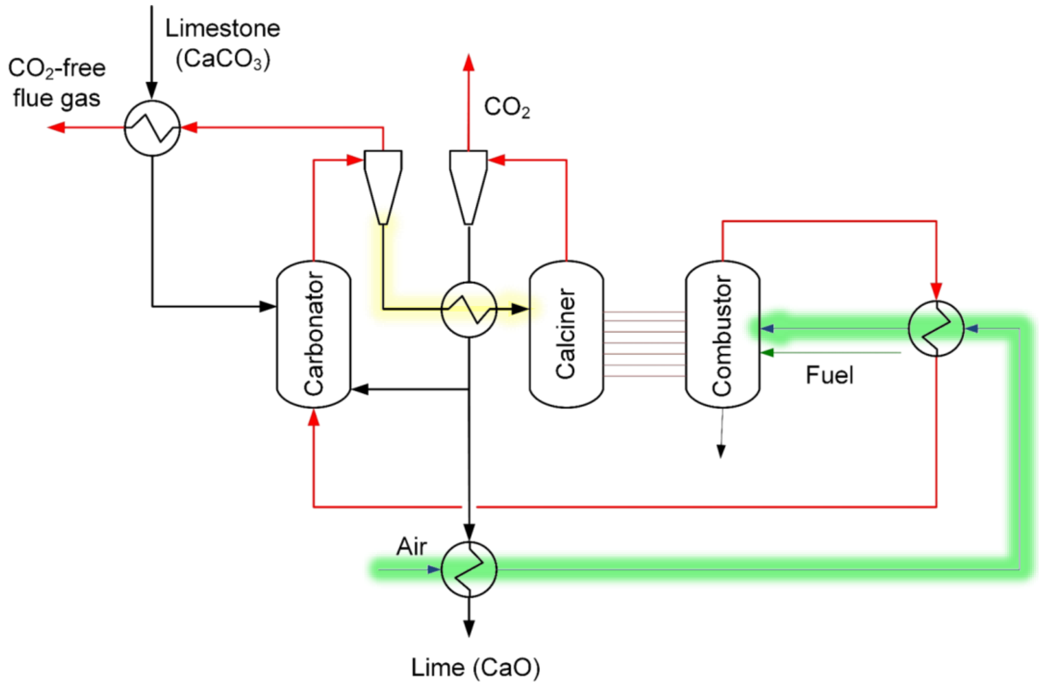


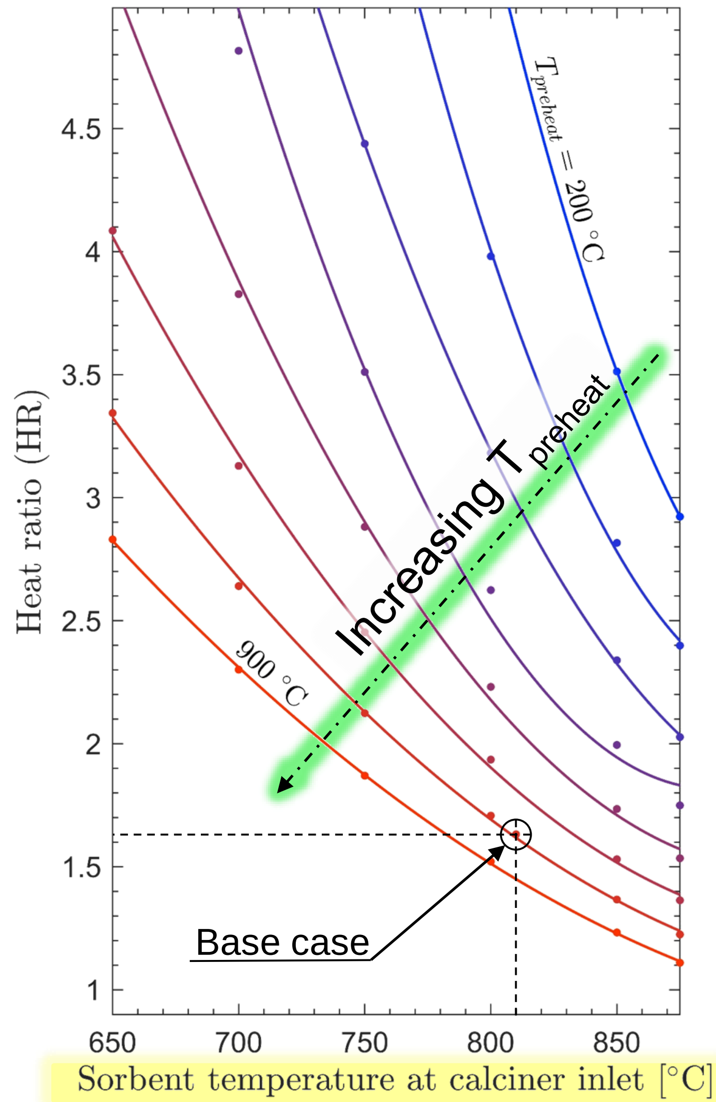
Results of the Base Case

- Increase in direct fuel consumption
- High product ratio for retrofit solution
  → Mass integration is very important
- Product ratio constant for full integration
- Reduction of direct CO_2 emissions
- Heat recovery power generation

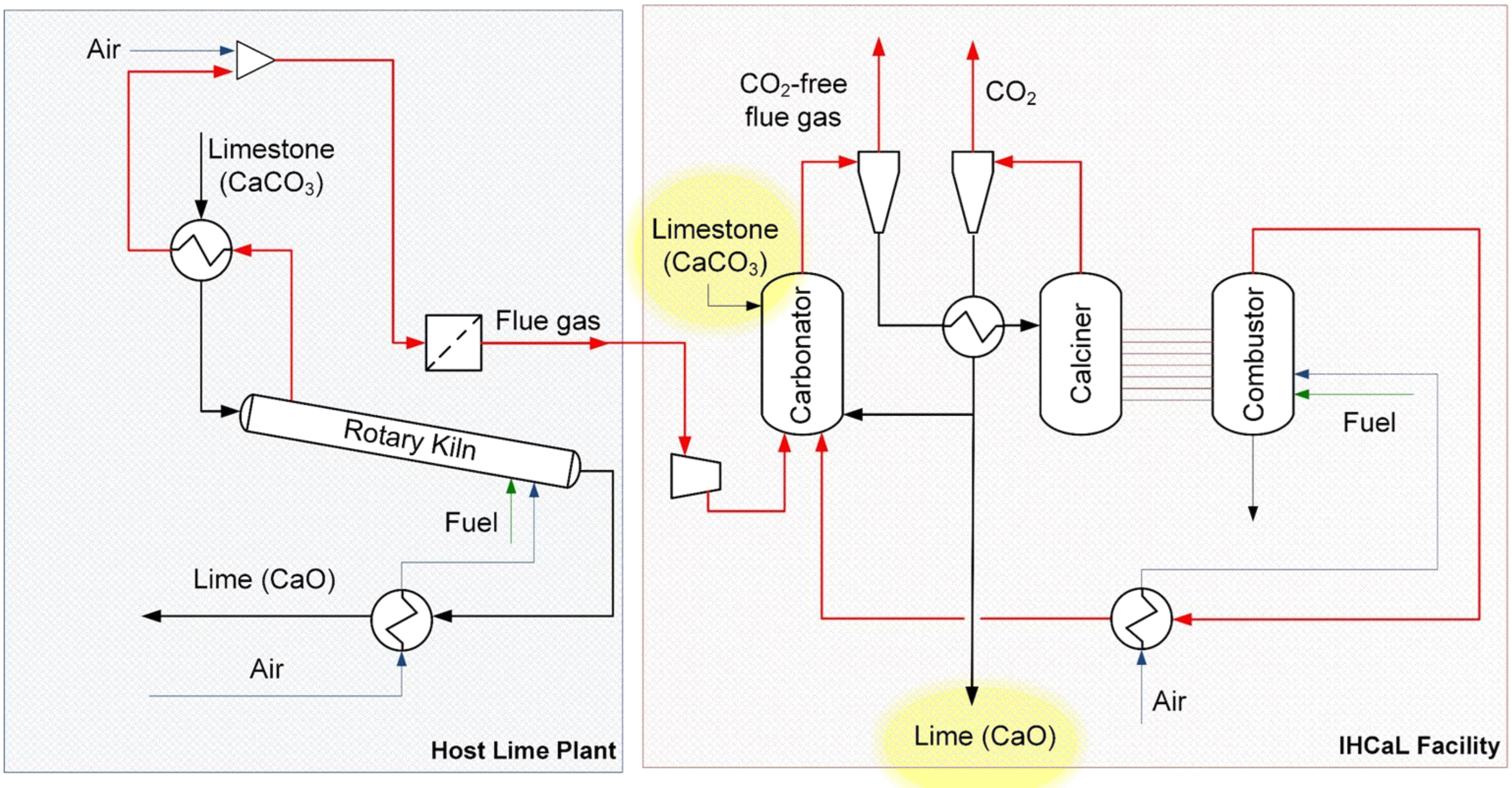


- Key integration points:
  - Solid/solid heat exchanger ($T_{sorb,calc,in}$)
  - Air preheater ($T_{preheat}$)
- Less heat penalty for full integration
  - ≈100% reduction



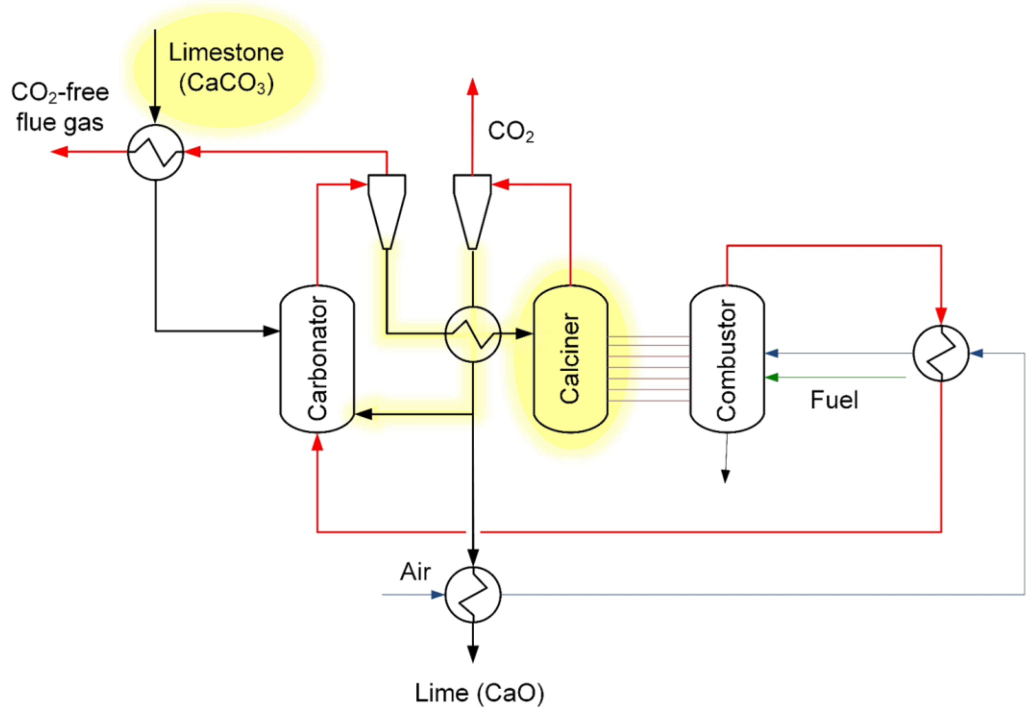


- Retrofit
  - High influence of make-up (Λ) in the production (PR)
  - Strong increase of the production (high values of PR)



- Retrofit
  - High influence of make-up (Λ) in the production (PR)
  - Strong increase of the production (high values of PR)

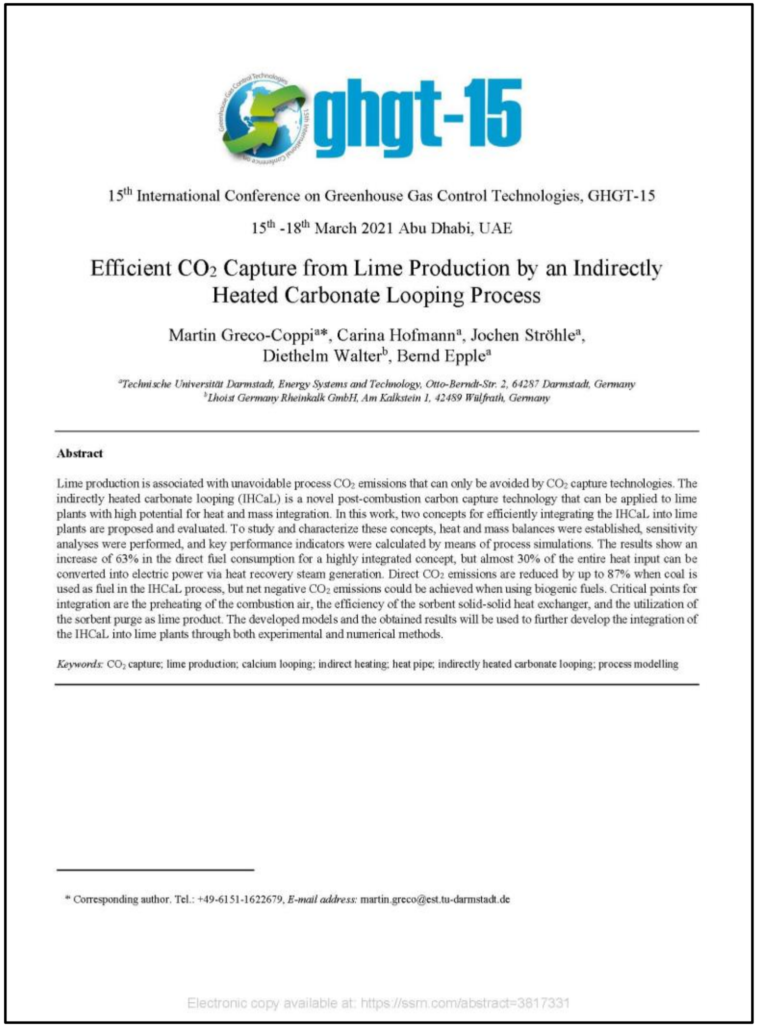
- Full integration
  - Specific make-up ratio is an output for the full integration → good sorbent activity
  - Majority of CO_2 produced in the calciner → less inventory requirement



Summary & Outlook

- **Key integration points**
  - Preheating of the combustion air
  - Efficient solid/solid heat exchanger (under development)
- Potential for net **negative CO_2 emissions**
  - Utilization of RDF with high biogenic content
  - CO_2 avoidance through power generation
- The results will serve as basis for **further research**
  - Upcoming test campaigns - 300 kW_{th} pilot plant -
  - Economic, environmental and risk analysis

Thank you for your attention!



ghgt-15

15th International Conference on Greenhouse Gas Control Technologies, GHGT-15

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Efficient CO_2 Capture from Lime Production by an Indirectly Heated Carbonate Looping Process

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Abstract

Lime production is associated with unavoidable process CO_2 emissions that can only be avoided by CO_2 capture technologies. The indirectly heated carbonate looping (IHCaL) is a novel post-combustion carbon capture technology that can be applied to lime plants with high potential for heat and mass integration. In this work, two concepts for efficiently integrating the IHCaL into lime plants are proposed and evaluated. To study and characterize these concepts, heat and mass balances were established, sensitivity analyses were performed, and key performance indicators were calculated by means of process simulations. The results show an increase of 63% in the direct fuel consumption for a highly integrated concept, but almost 30% of the entire heat input can be converted into electric power via heat recovery steam generation. Direct CO_2 emissions are reduced by up to 87% when coal is used as fuel in the IHCaL process, but net negative CO_2 emissions could be achieved when using biogenic fuels. Critical points for integration are the preheating of the combustion air, the efficiency of the sorbent solid-solid heat exchanger, and the utilization of the sorbent purge as lime product. The developed models and the obtained results will be used to further develop the integration of the IHCaL into lime plants through both experimental and numerical methods.

Keywords: CO_2 capture; lime production; calcium looping; indirect heating; heat pipe; indirectly heated carbonate looping; process modelling

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