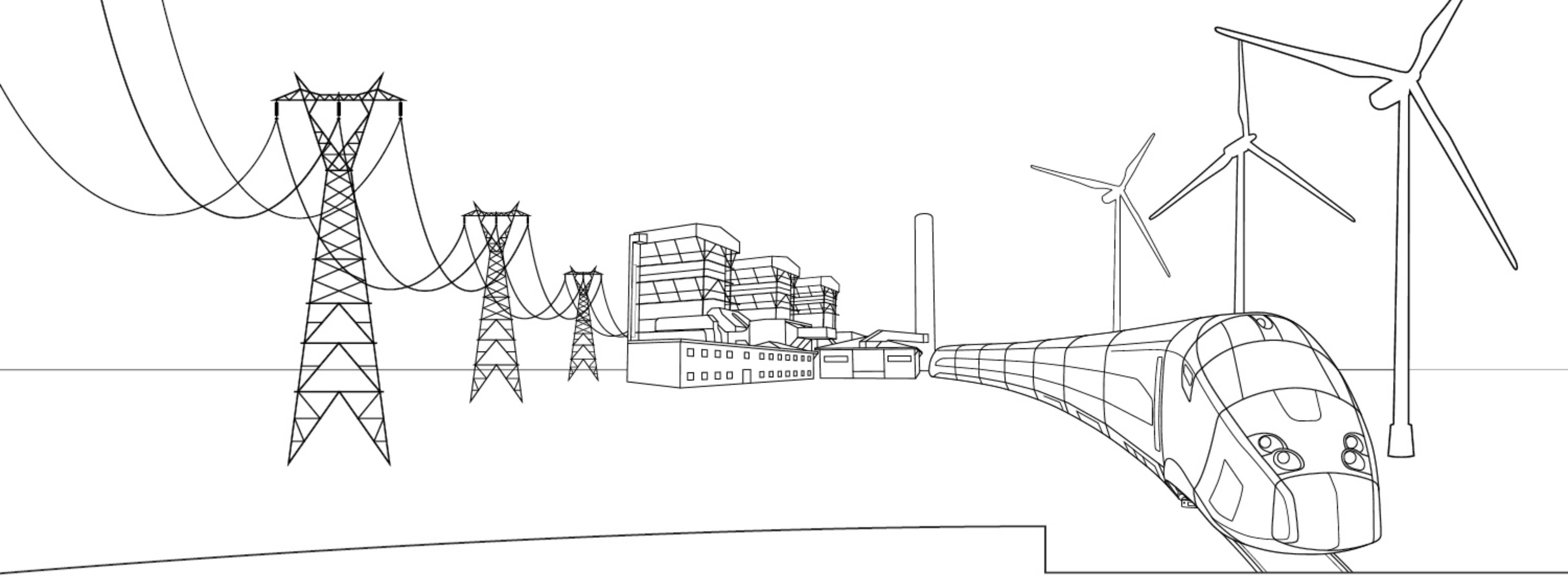

Alstom's Regenerative Calcium Cycle – Results and Future Perspective

Norcem CO_2 Capture Project - Int. CCS Conference

M. Balfe

Langesund May 20th-21st 2015

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Agenda

- **Introduction**
- RCC – Cement Plant Integration Considerations
- RCC Benchmarking Input - Case 2
- Future RCC Development - Indirect Heated Calcination
- Conclusions and Outlook

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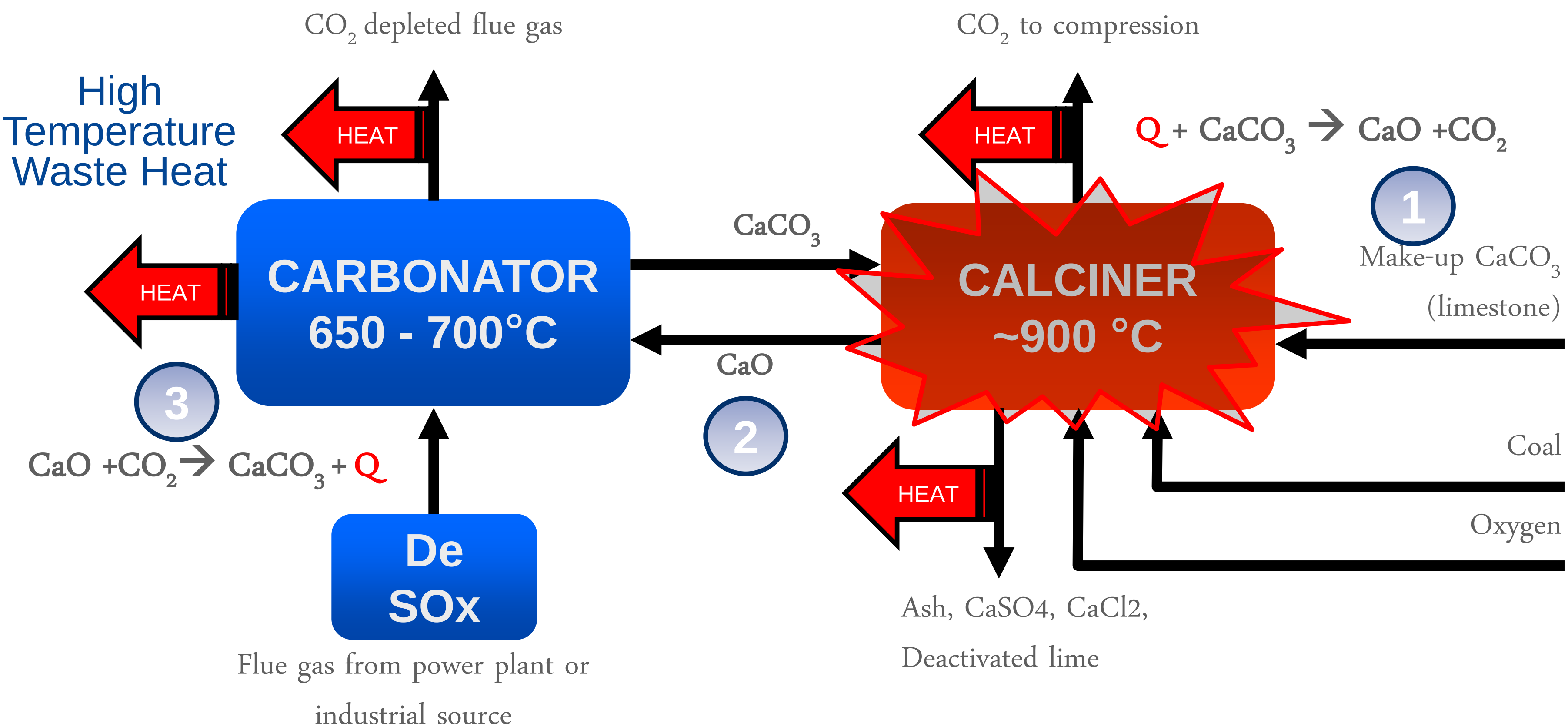
Regenerative Calcium Cycle
Direct Fired Calciner - Basic Process Flow



1) Separate CO_2 from raw meal 2) produce activated CO_2 capture sorbent 3) generate power from heat of CO_2 adsorption.

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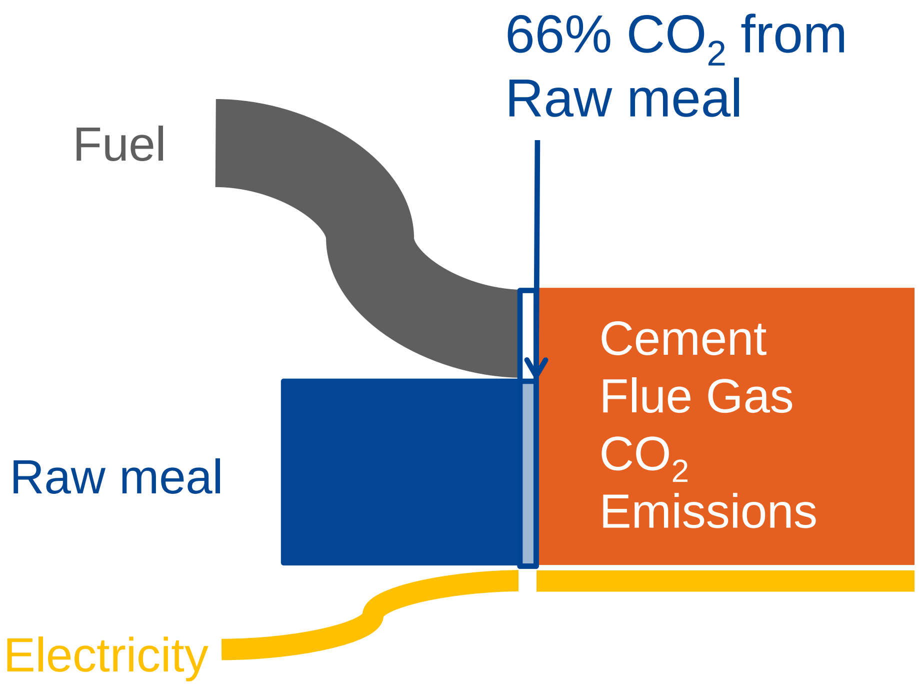
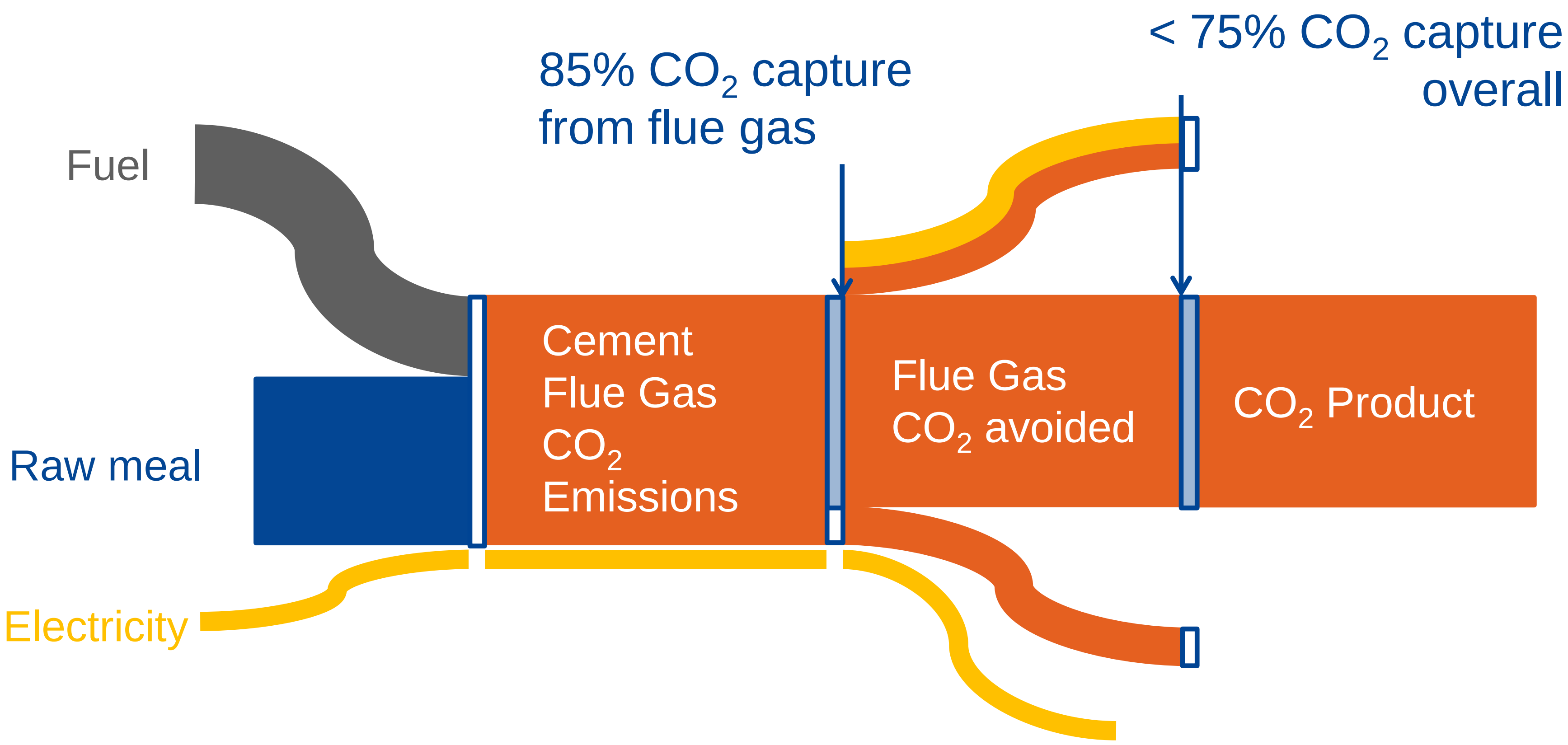
Generic Cement Plant (Base Case or Brevik)
Sankey Analysis: CO_2 equivalent



The Bulk CO_2 emissions are associated with raw meal calcination (not including electrical consumption).

“End of the Pipe” Solvent Based Process

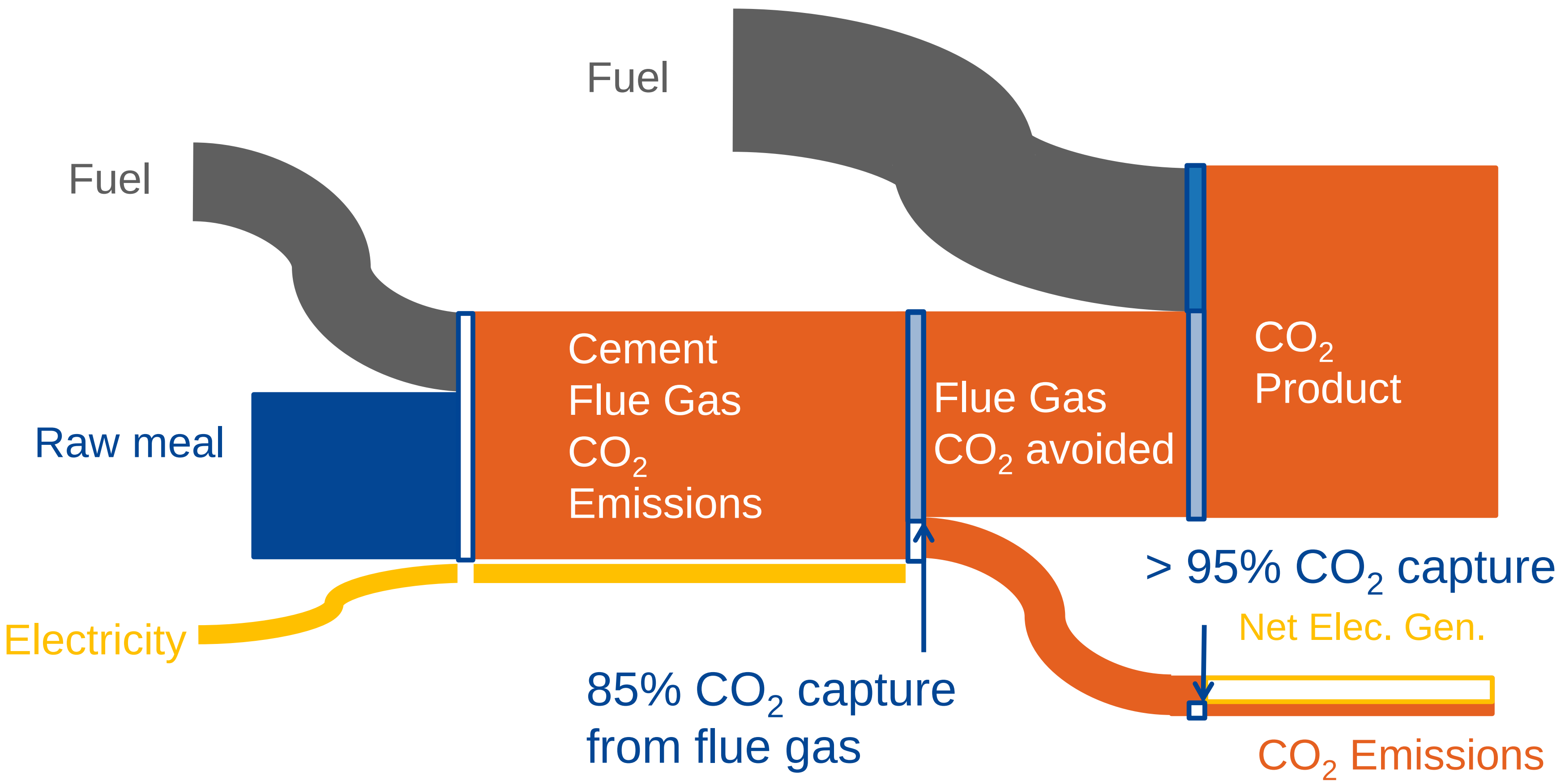
Sankey Analysis: CO_2 equivalent



Solvent based methods require electricity and heat to capture CO_2.

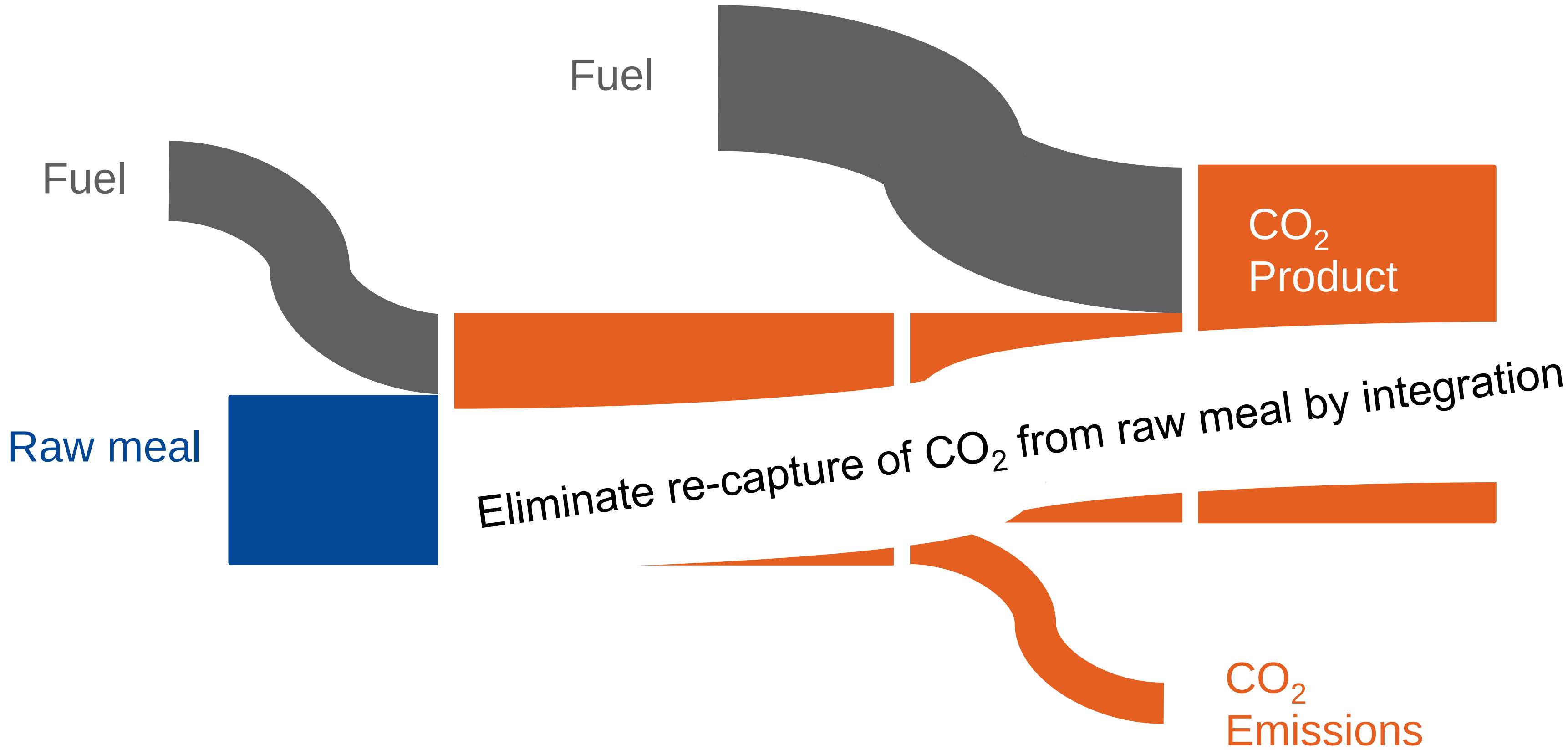
“End of the Pipe” RCC - Cement Plant

Sankey Analysis: CO_2 equivalent



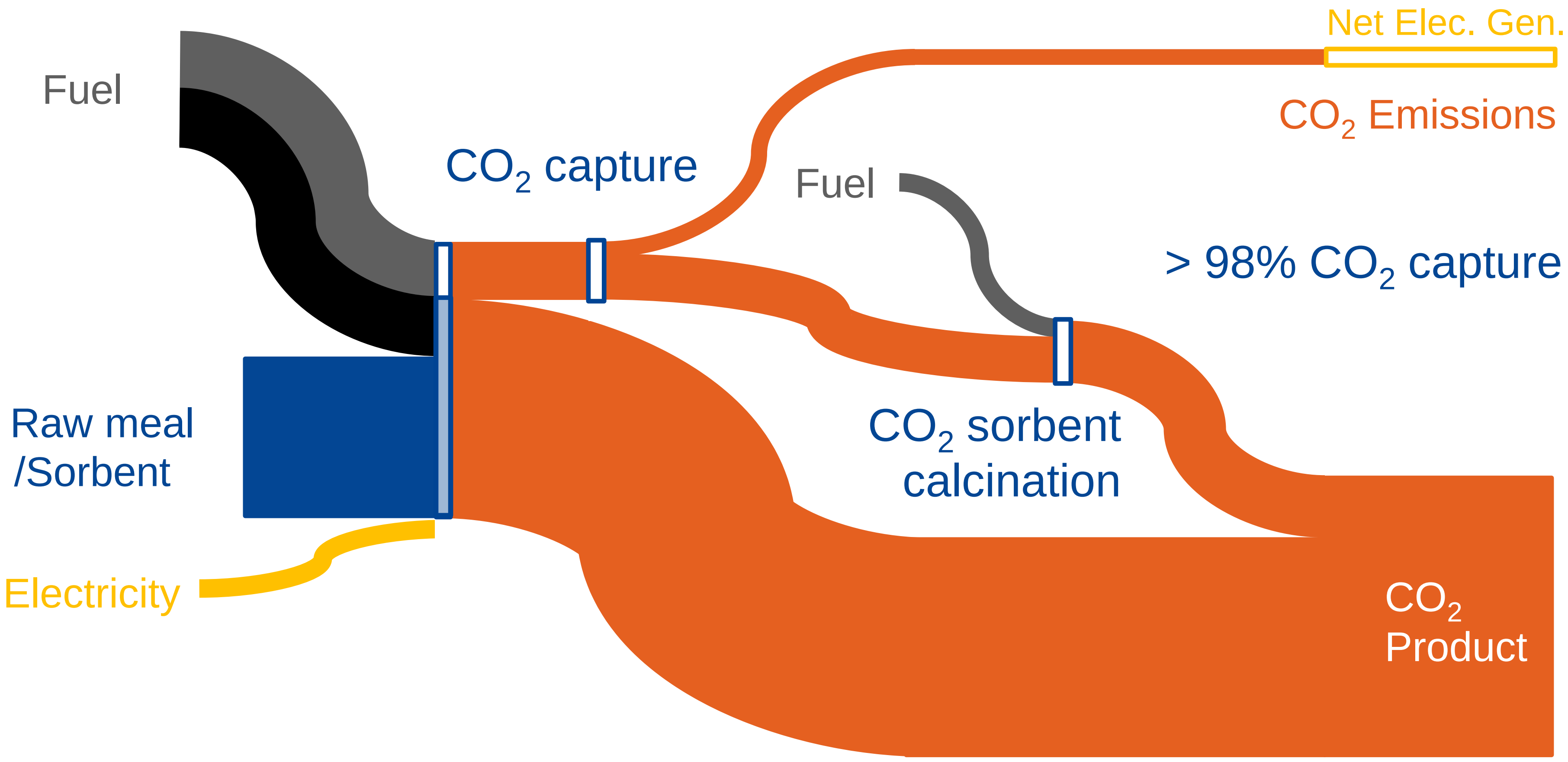
RCC produces electricity, impacting CO_2 Emissions or Heating Rate.

“End of the Pipe” RCC - Cement Plant
Sankey Analysis: CO_2 equivalent



Motivation to conduct initial oxy-fired calcination of raw meal.

"Integrated" RCC – Cement Plant
Sankey Analysis: CO_2 equivalent



Separate CO_2 from raw meal, reduce capture plant size, and minimize CO_2 footprint!

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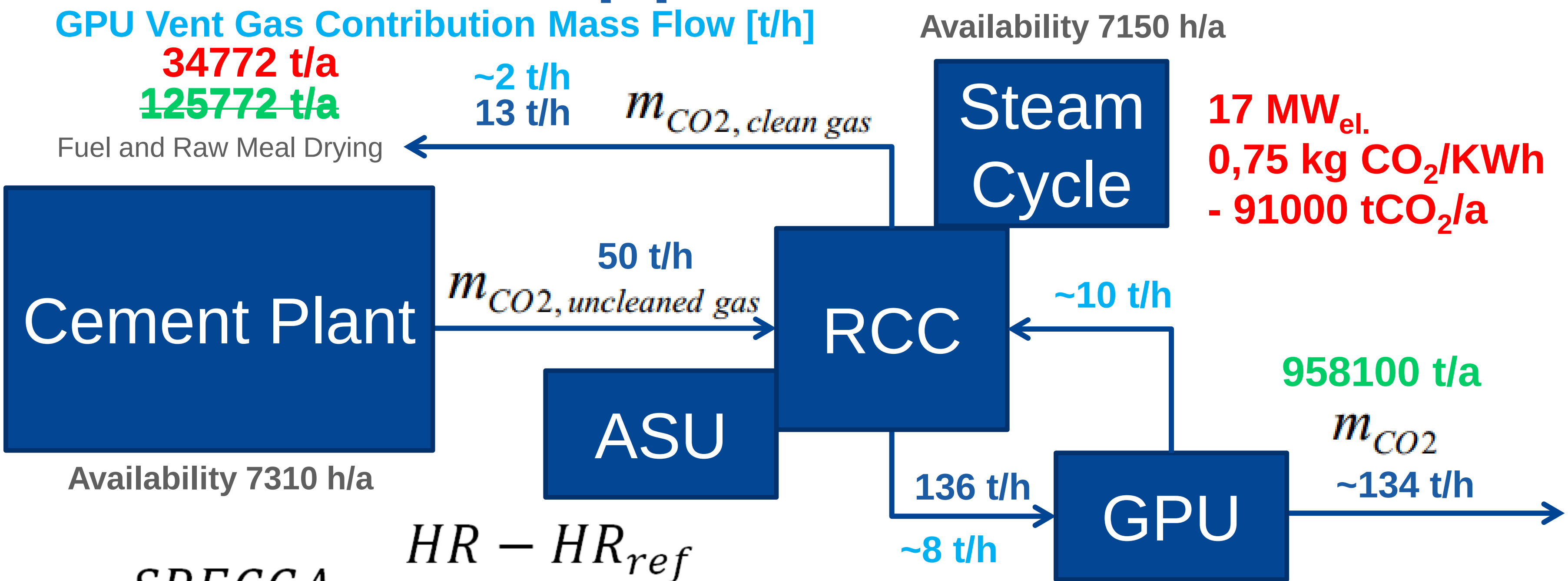
“End of the Pipe Brevik” Benchmarking Basis

RCC “End of the Pipe Brevik”: 85 % (96 %)

Annual Emission [t/a]
Instantaneous Ave. Mass Flow [t/h]
GPU Vent Gas Contribution Mass Flow [t/h]



$$SPECCA = \frac{HR - HR_{ref}}{E_{ref} - E}$$

Calculations **consider cement and CO_2 capture plant availability**. 85% capture is obtained with a **Carbonator capture rate of only 75%.**

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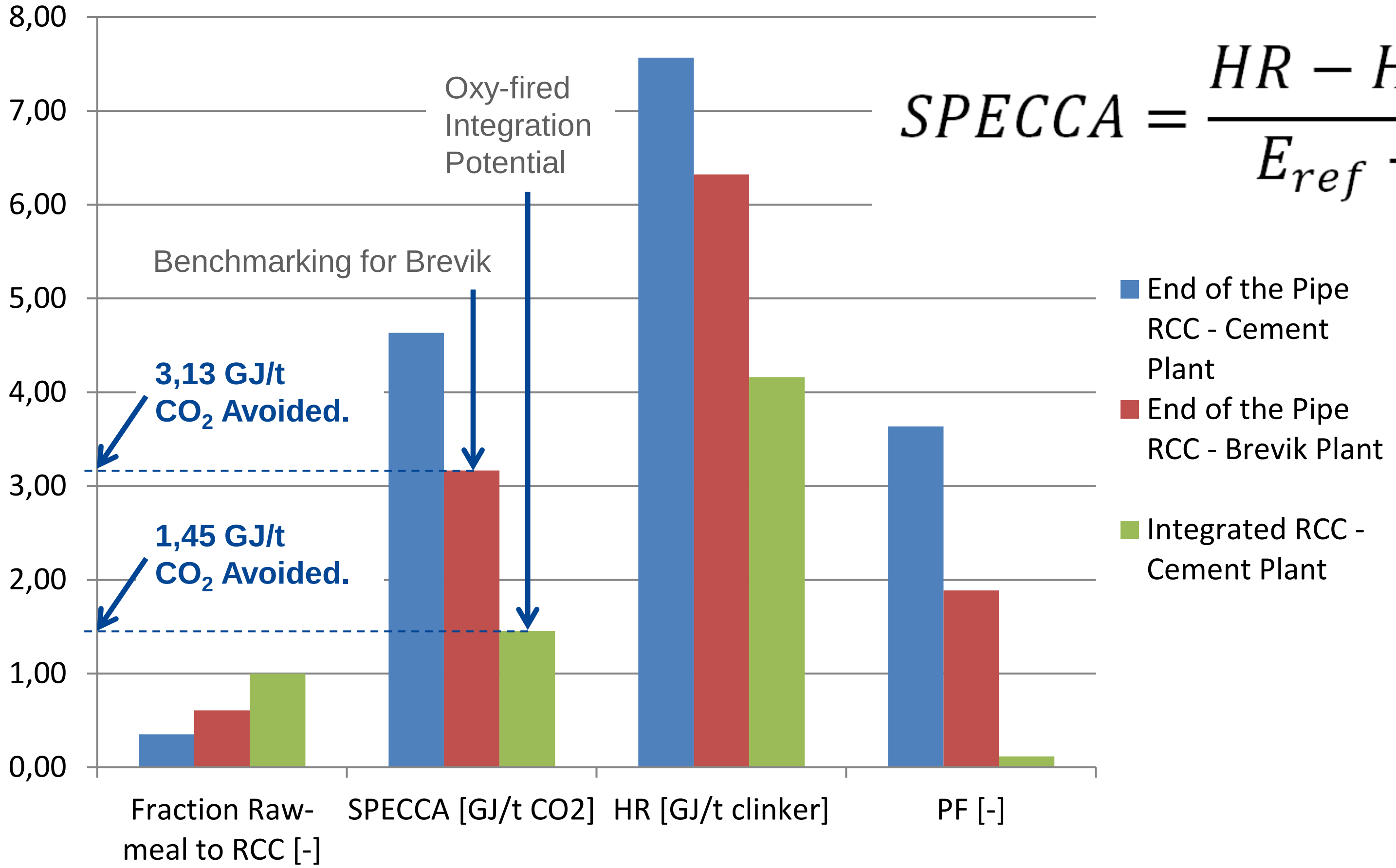
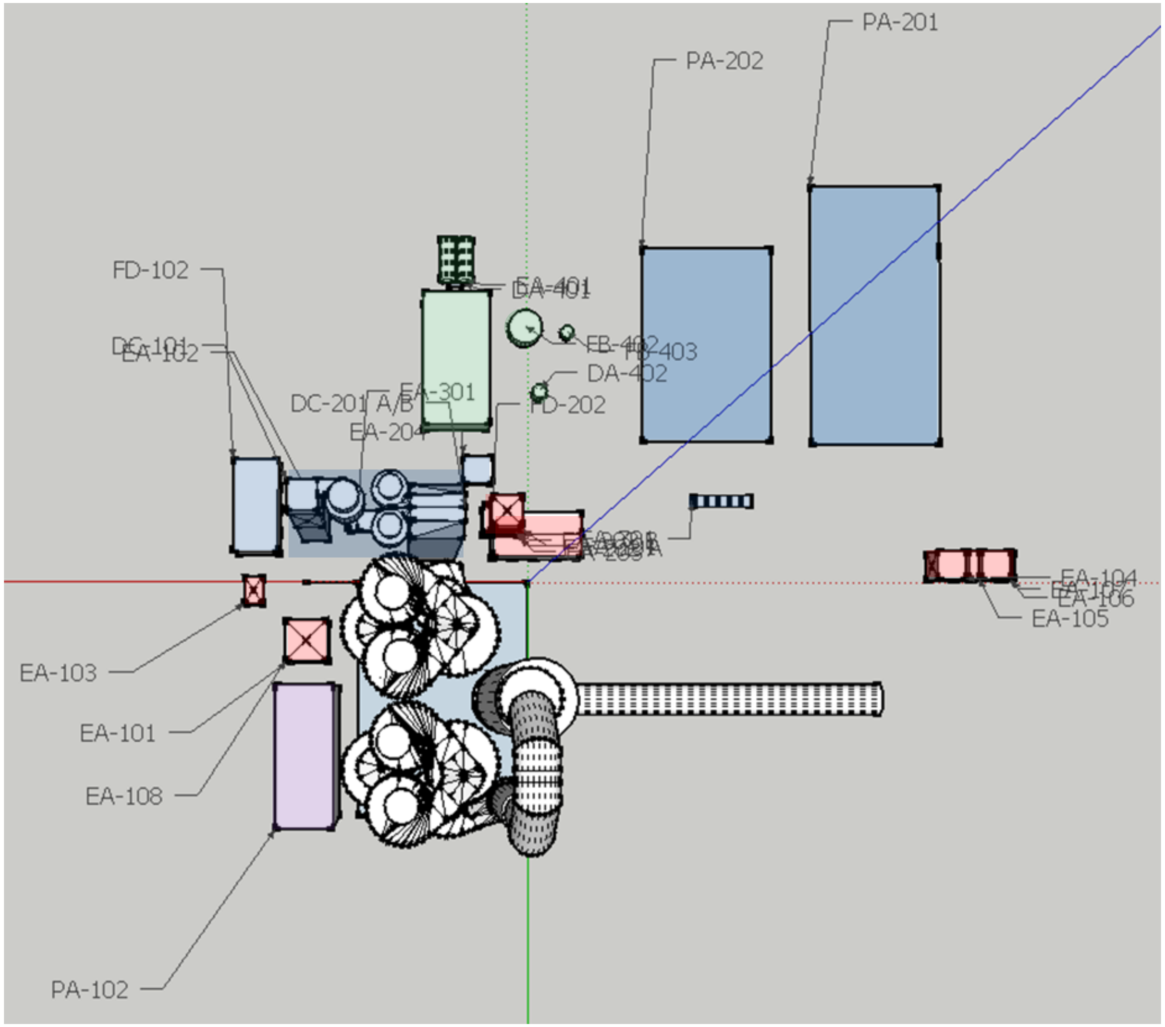
"Integrated" RCC – Cement Plant
SPECCA Reduction with Integration



$$SPECCA = \frac{HR - HR_{ref}}{E_{ref} - E}$$

Great potential for integrated/green field solutions

“End of the Pipe” RCC – Brevik Cement Plant
Rough Plot Layout



- RCC CO_2 capture CAPEX costs are less than for equivalent solvent based capture process.
- Intrinsic power generation increases total installed cost by 25% but provides a positive OPEX.

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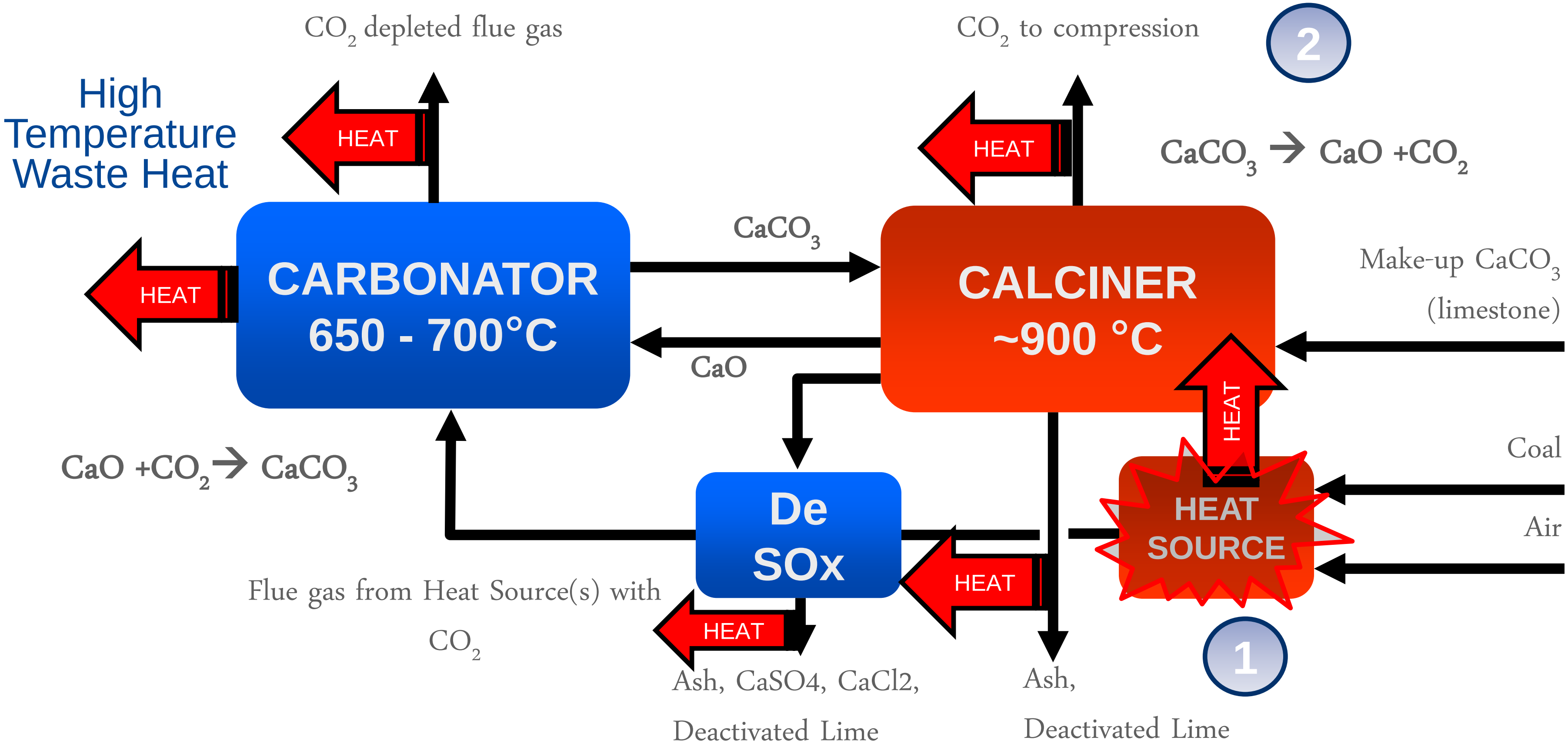
Emerging RCC Process Concepts
Indirect Fired Calciner (Pilot Concept Development)



Air separation unit is avoided by high temperature heat transfer; high quality CO_2 simplifies downstream processing.

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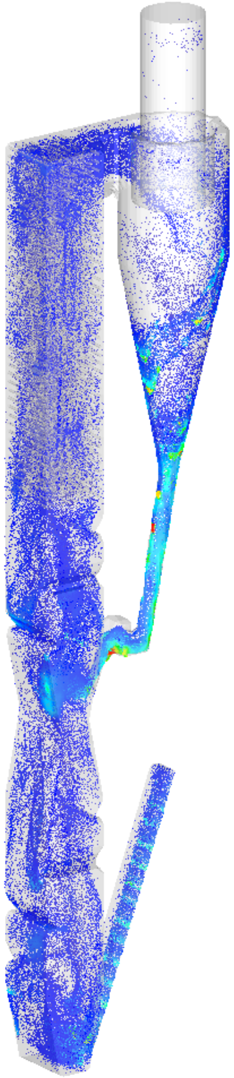
Conclusions

- The marriage of RCC with oxy-fired calcination for cement production provides a strong process synergy.
- Upstream calcination isolates the bulk of CO_2 from raw meal which improves efficiency and reduces cost.
- Activated raw meal from calcination is well suited for CO_2 capture and allows very high capture rates with conventional air-fired kilns.
- RCC technology is ready for “risk free” integration into cement production facilities.



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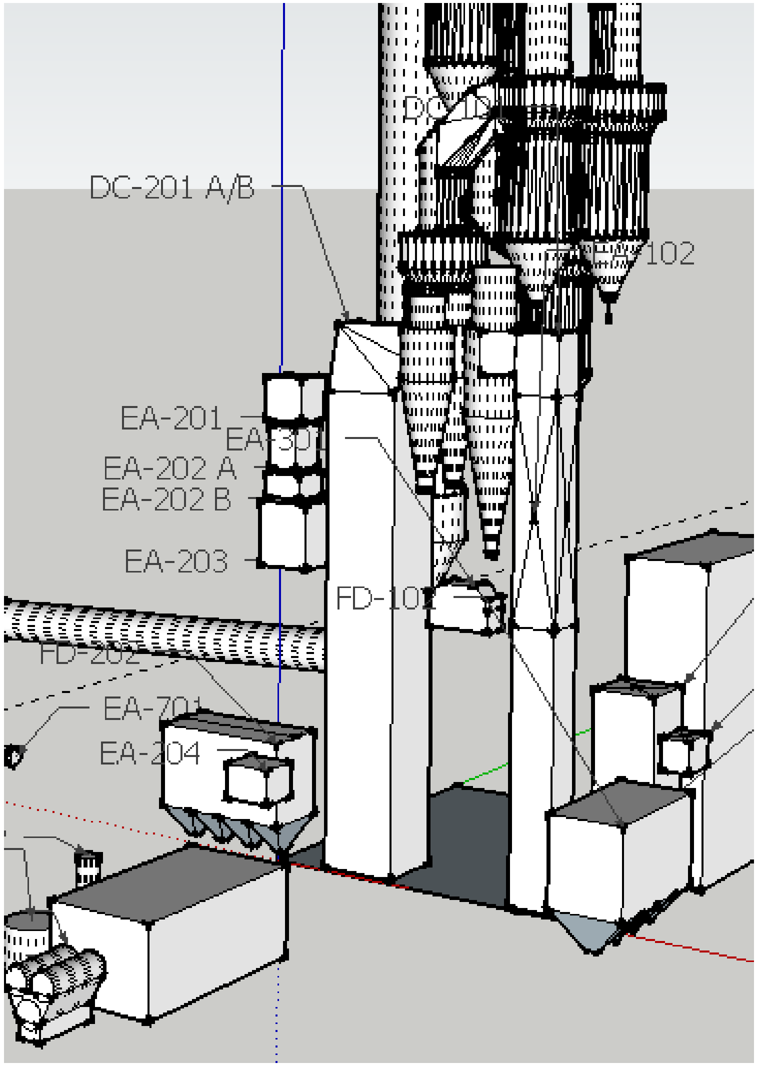
Outlook

- Attractive oxy-fired RCC integration options provide attainable solutions for efficiently capturing CO_2 from cement production (SPECCA = 1.45 GJ/t CO_2).
- Emerging indirectly heated RCC concepts provide an attractive mid-term prospect to lower overall cost by ASU elimination.
- ALSTOM is still seeking collaboration opportunities with industrial partners to share the knowledge around RCC for cement and reduce cost for development.



Project Partners
RCC Derisking & Benchmarking Study

NORCEM HEIDELBERGCEMENT Group

HEIDELBERGCEMENT

ecra european cement research academy

CLIMIT

GASSNOVA

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Derisking and Benchmarking of RCC technology for application to cement production considering process performance and integration.

Project Partners
Future RCC Pilot Plant

NORCEM HEIDELBERGCEMENT Group

HEIDELBERGCEMENT

ecra european cement research academy

CLIMIT

GASSNOVA

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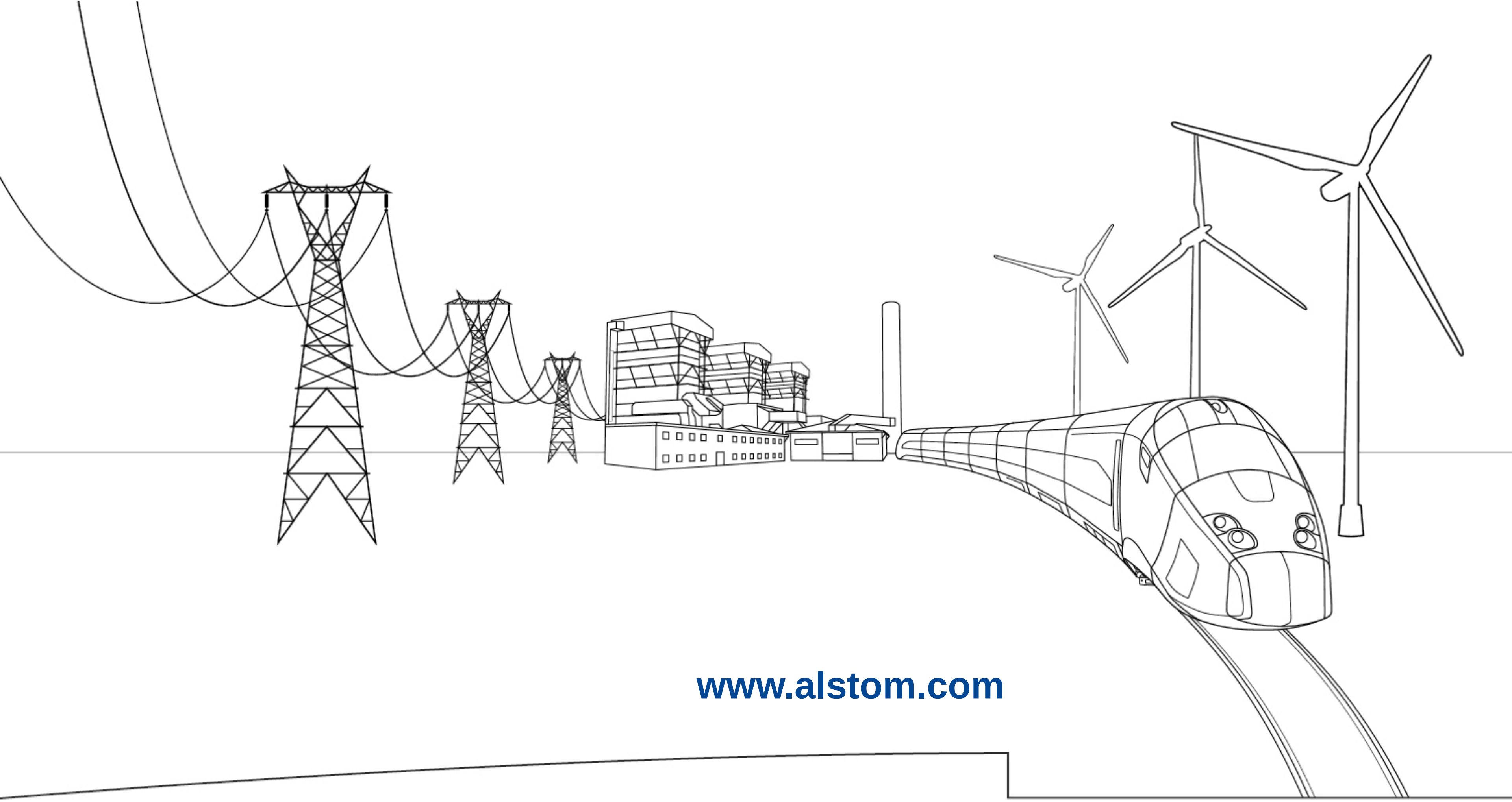
RCC Pilot

RCC integrated into a cement production facility.

Network of common interest partners to demonstrate the technology allowing closure of the sorbent loop by cement production.



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Thank you!
Questions?

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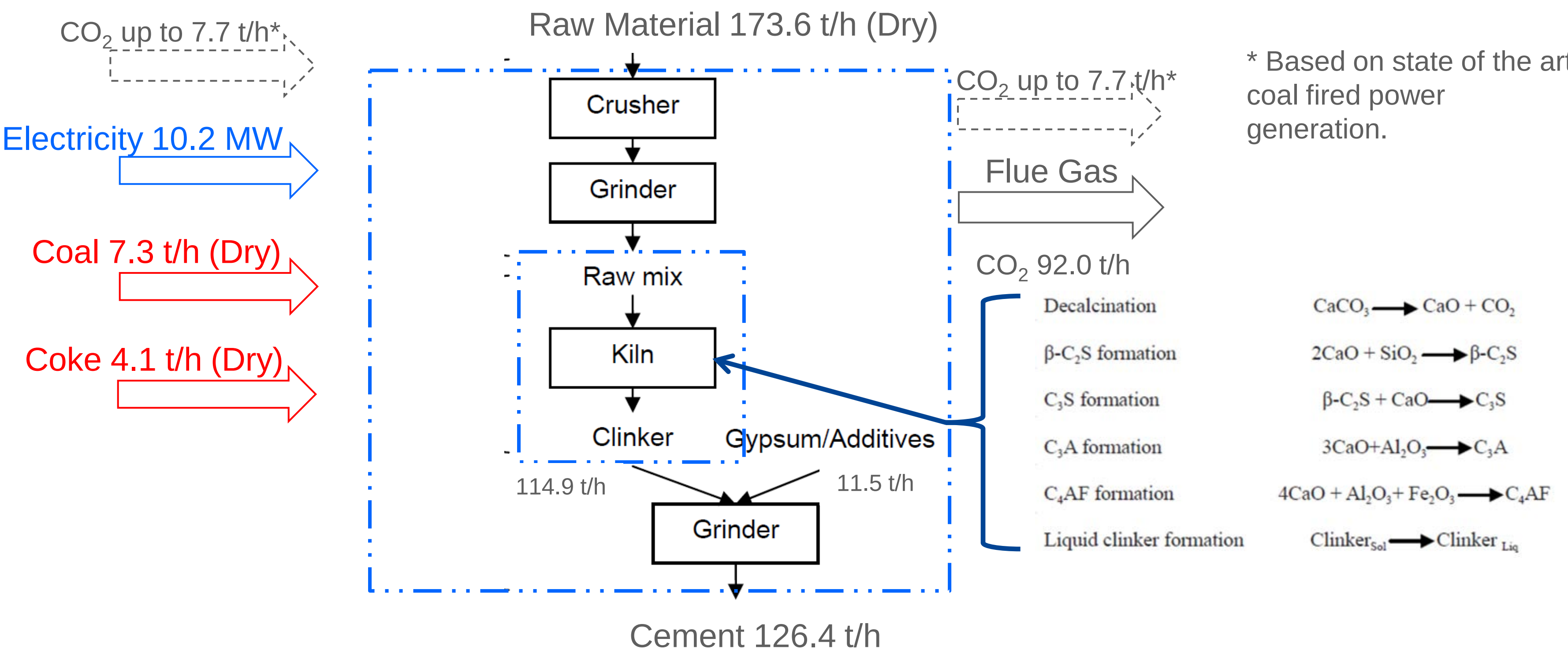
"State of the Art" Cement Plant
Overall process model to support RCC integration



* Based on state of the art coal fired power generation.

$$SPECCA = \frac{HR - HR_{ref}}{E_{ref} - E}$$

Evaluate increase in Heating Rate to reduce CO_2 emissions.

IEAGHG (2008), "CO2 Capture in the Cement Industry".

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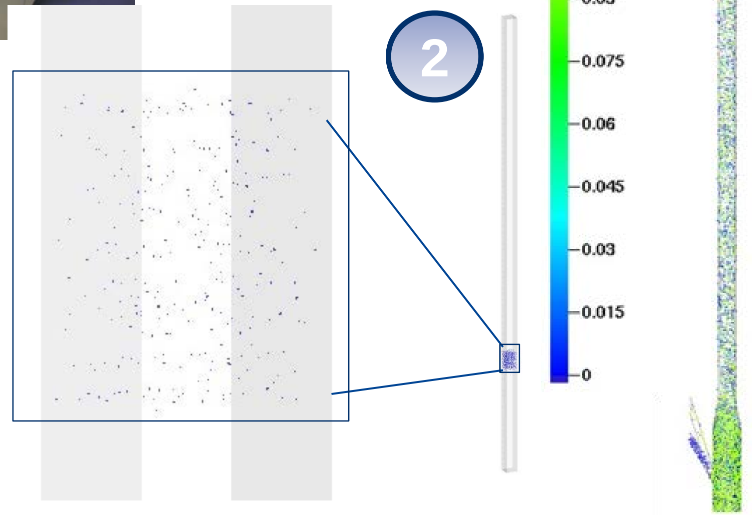
Model Development and Validation
Mechanistic Model Development Pathway



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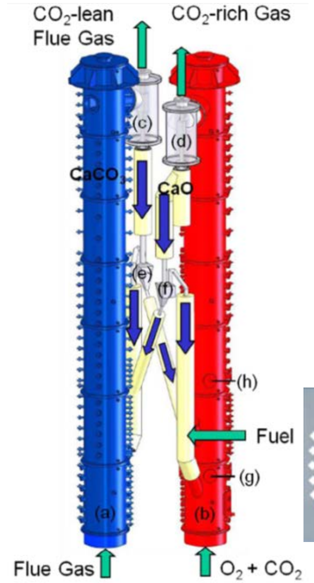
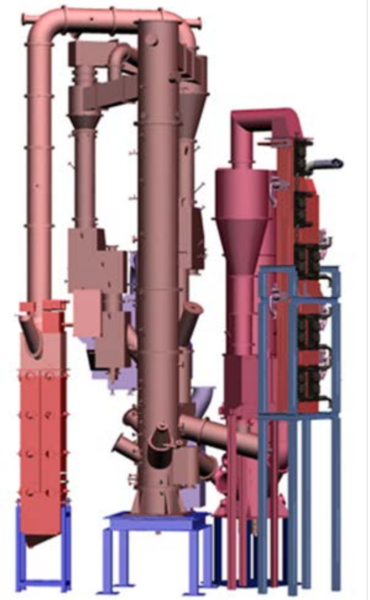
IFK, Stuttgart



EST, Darmstadt



TGA → Virtual TGA & 3D Simulations ←→ Pilot Result

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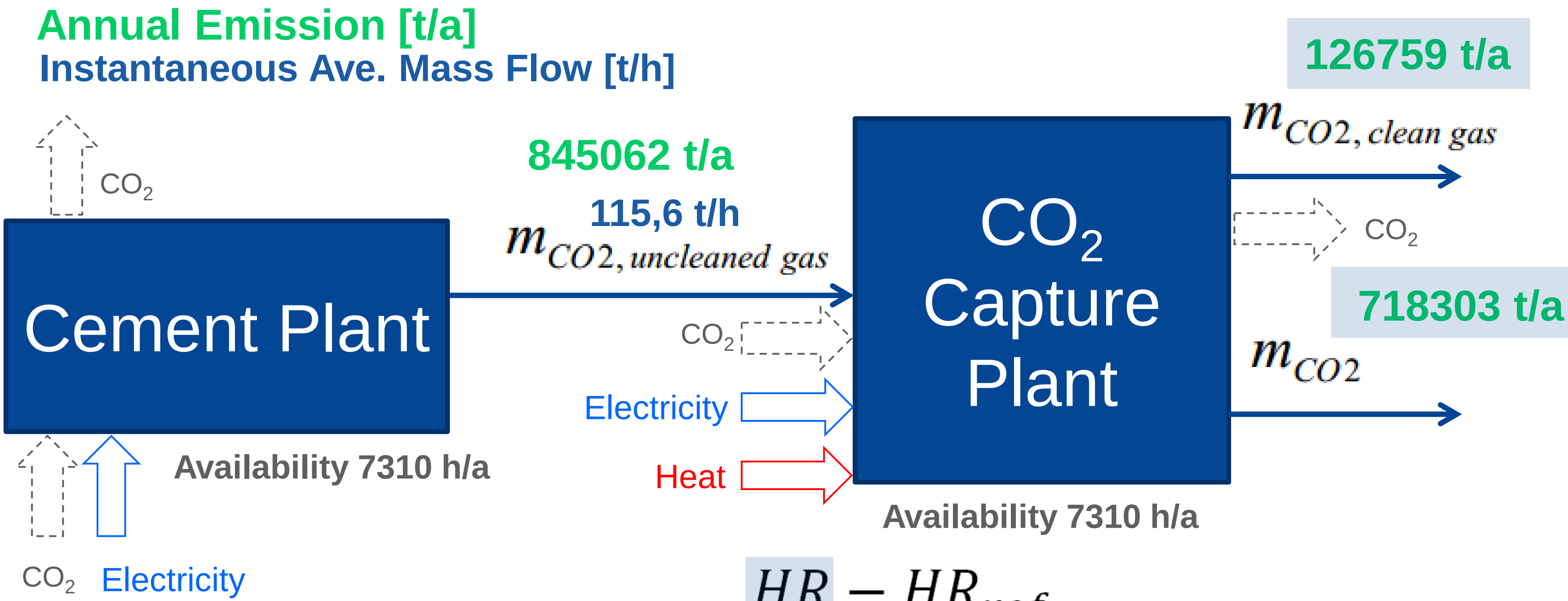
Generic CO_2 Capture Case

CO_2 footprint considering the influence of external utilities

Post Combustion: **85% Capture**



$$SPECCA = \frac{HR - HR_{ref}}{E_{ref} - E}$$

Import power and heat influence CO_2 emissions.