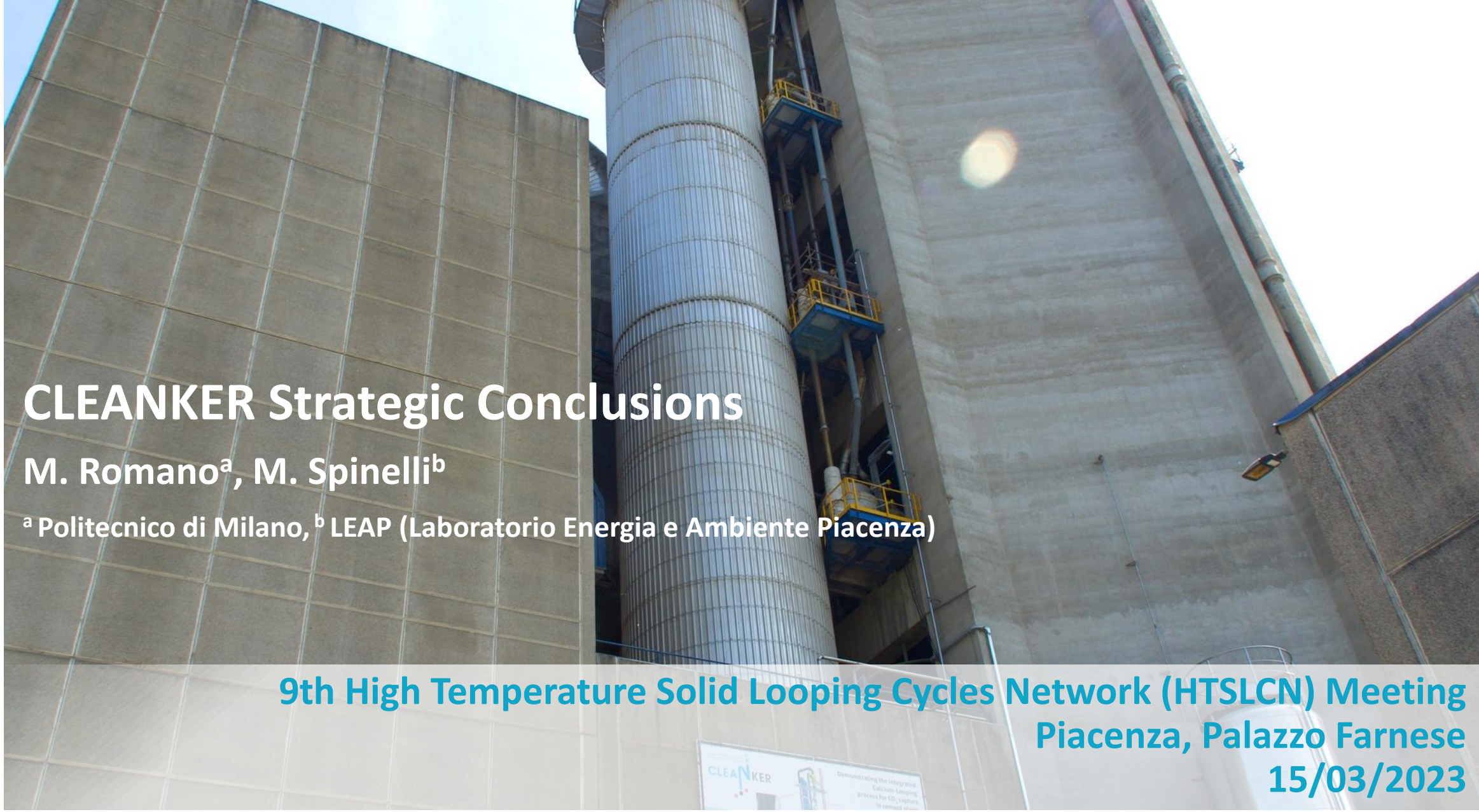

CLEANKER Strategic Conclusions

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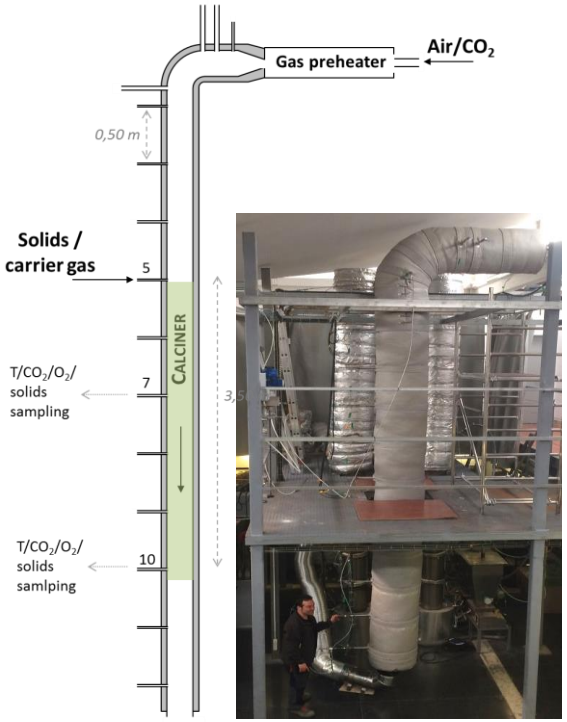
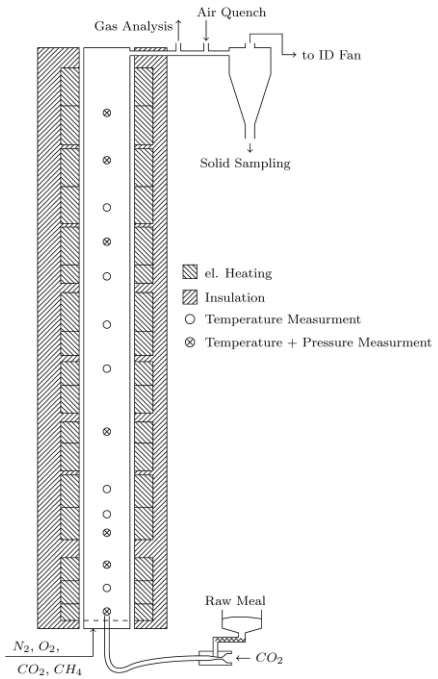
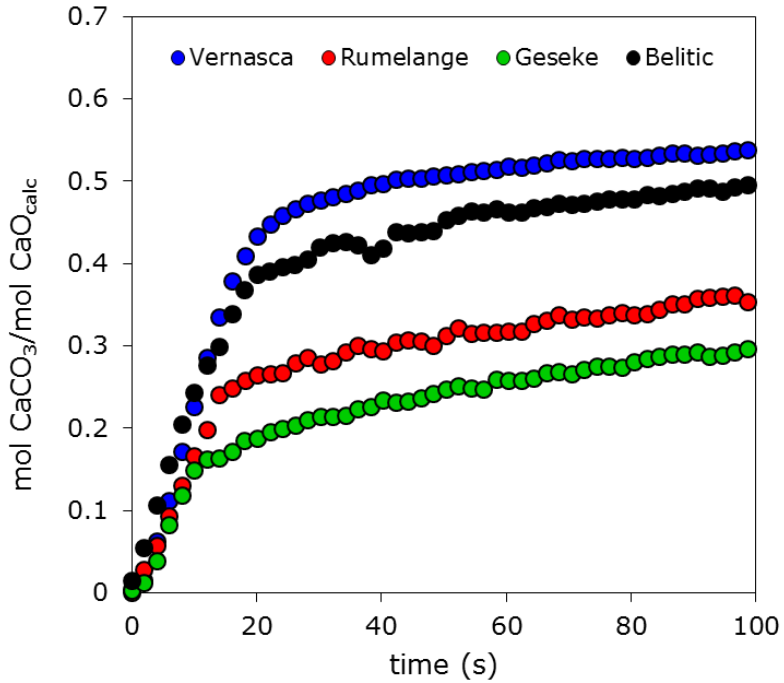
9th High Temperature Solid Looping Cycles Network (HTSLCN) Meeting
Piacenza, Palazzo Farnese
15/03/2023

Raw meal as CO_2 sorbent

- Extensive experience has been built at CSIC and USTUTT in the characterization of raw meals for the CaL process (carbonation, calcination sulfation via TGA, drop-tube and entrained flow reactors.
- Belite formation in the calciner hinders the CO_2 capture capacity of calcined raw meal.
- From lab tests, calcined raw meals retain variable (but sufficient) CO_2 capture capacity for CaL process.







Contact CSIC and USTUTT to have your raw meal characterized as CO_2 sorbent for CaL

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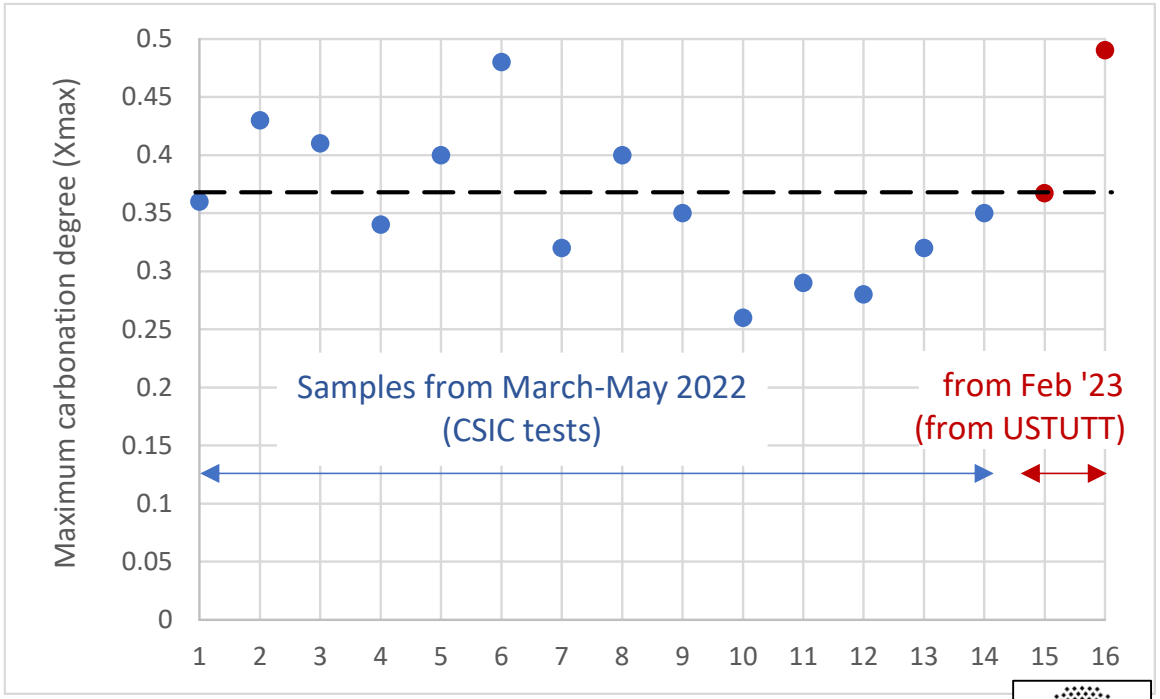
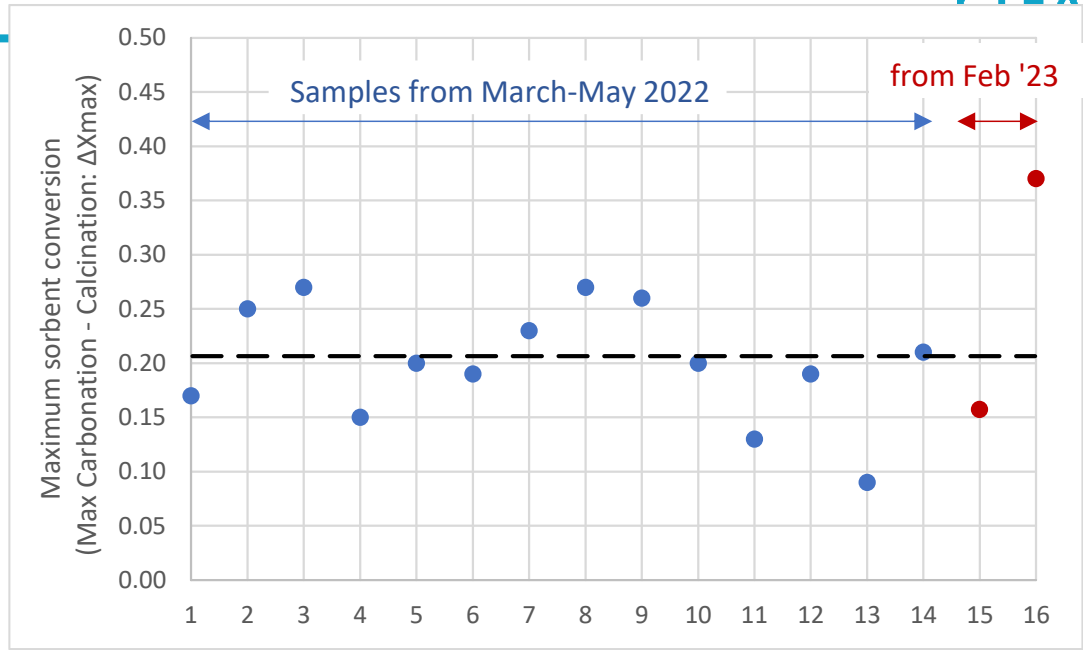
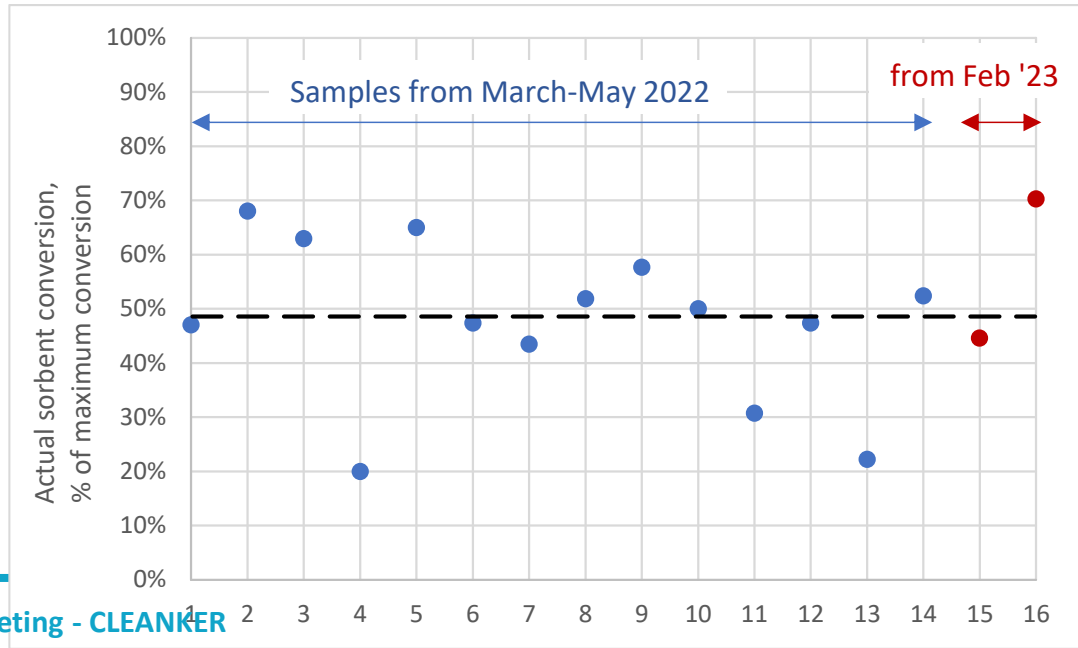
Raw meal as CO_2 sorbent

- Samples taken from the pilot show a slightly lower maximum recarbonation degree compared to lab-calcined raw meal
- Samples from the pilot retain sufficient carbonation capacity







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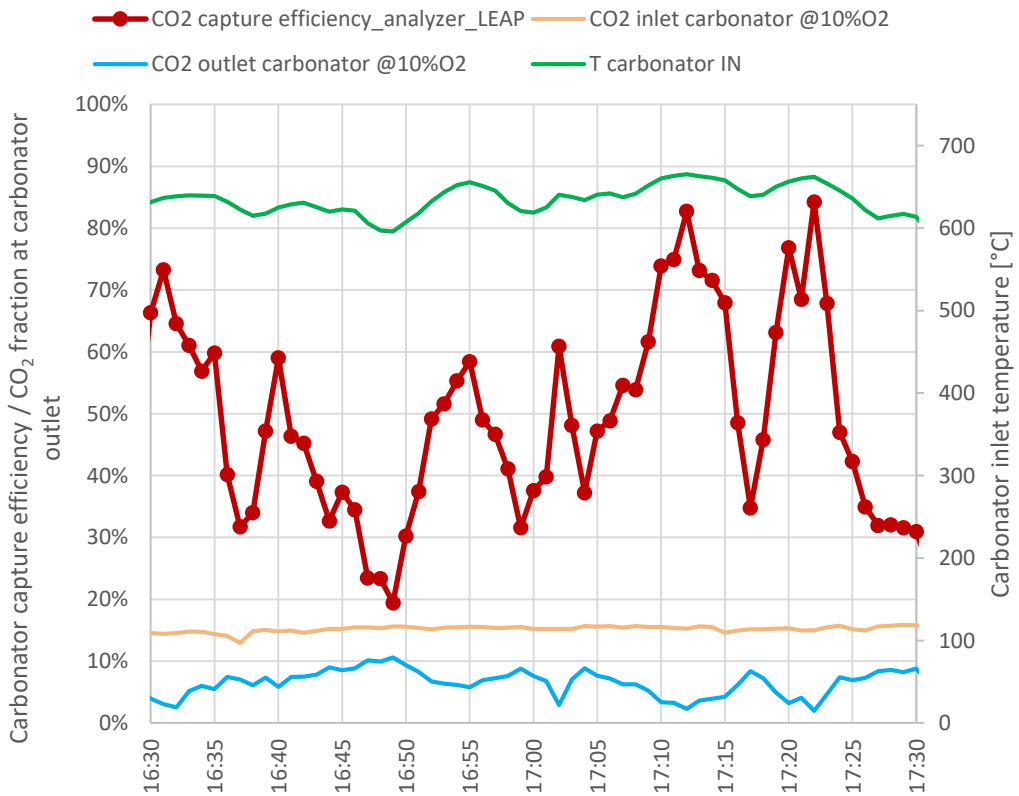
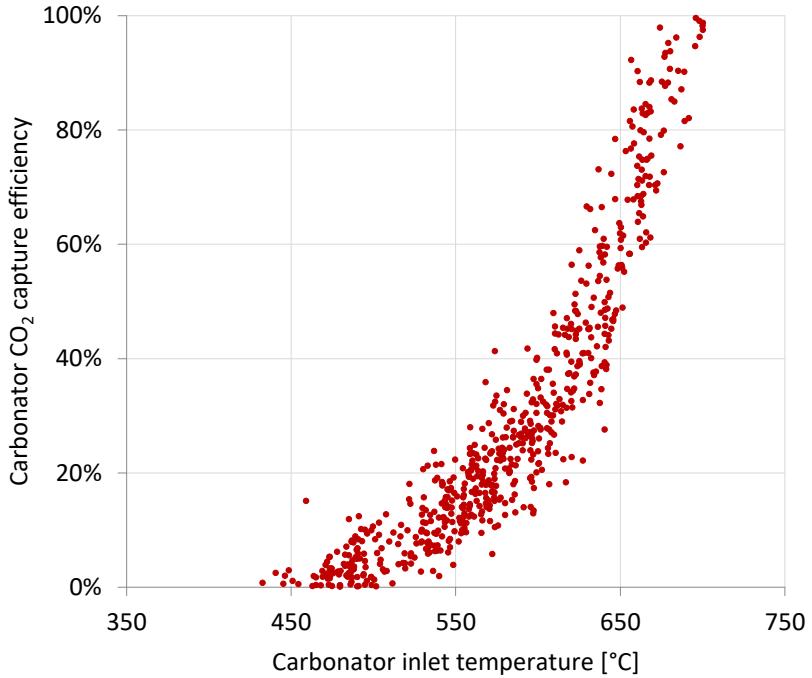
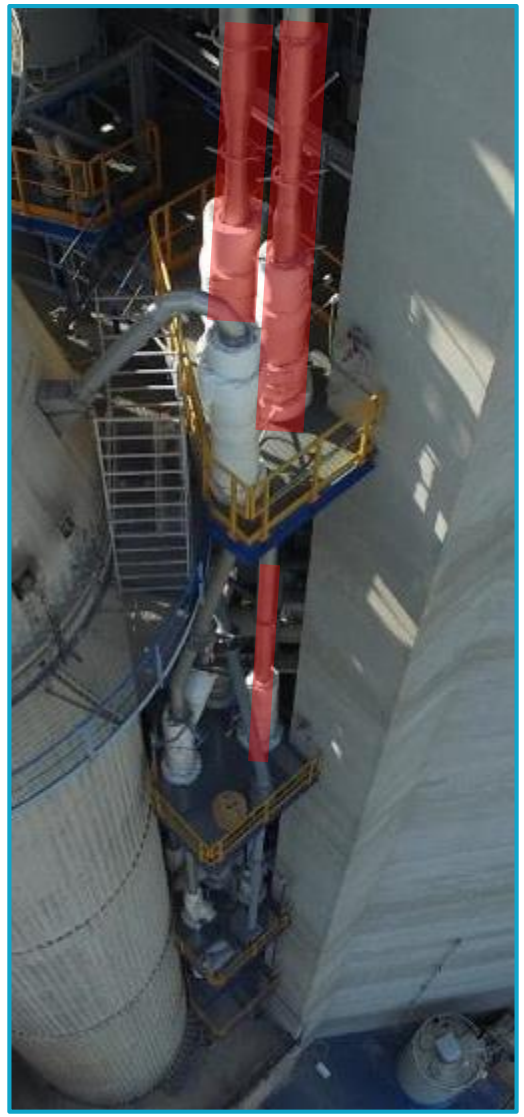
Pilot plant: Carbonator

- Intrinsic limitations of the pilot plant (complexity, small ducts, difficult fuel, low inertia) prevented the achievement of long periods of stable operation.
- Nevertheless, reasonably long periods with good carbonator capture efficiency (40-70%) has been achieved. *<u>Important</u>: 40-70% of carbonator capture efficiency corresponds to ~80-90% of total equivalent capture efficiency.*

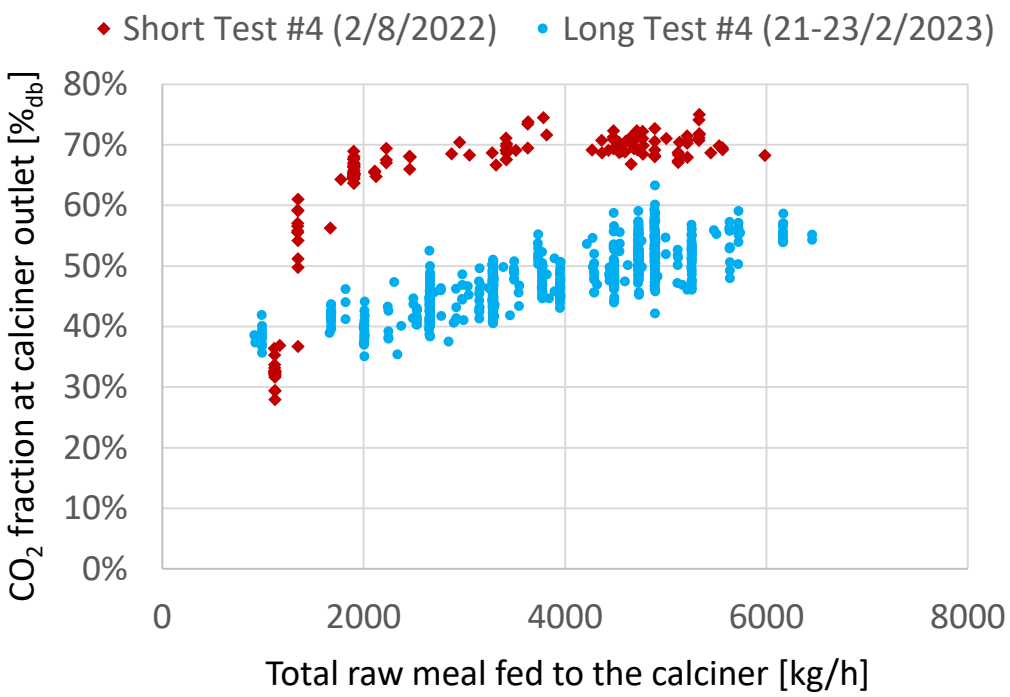


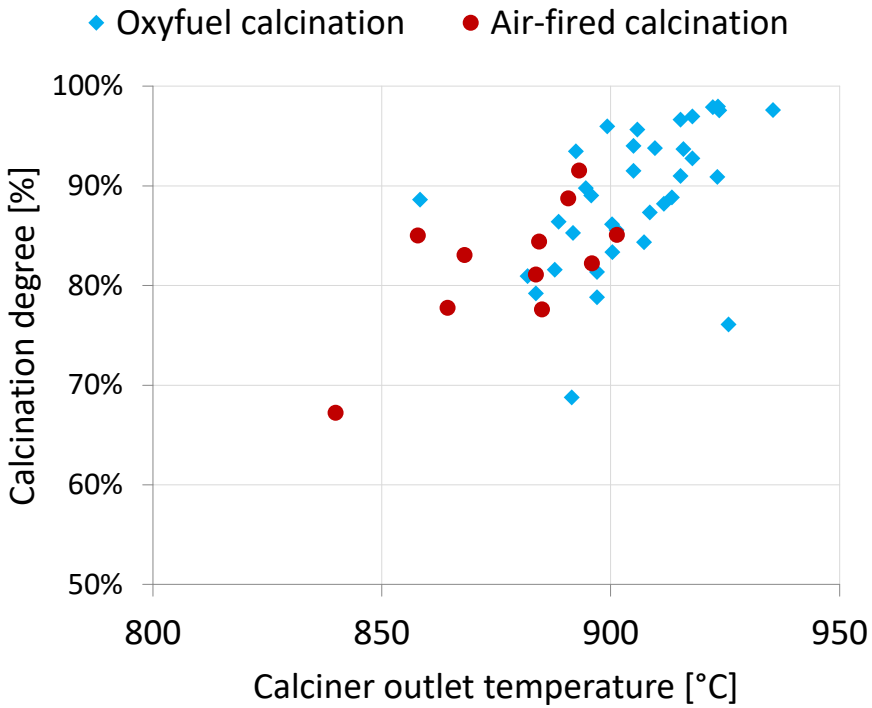




Pilot plant: Calciner

- No significant problems to report in operating the oxyfuel calciner (after switching from the initial high viscosity fuel to lighter fuel)
- The small size prevented the achievement of high CO_2 concentration in the flue gas, that declined form ~80% of initial tests to ~50% in the latest ones.





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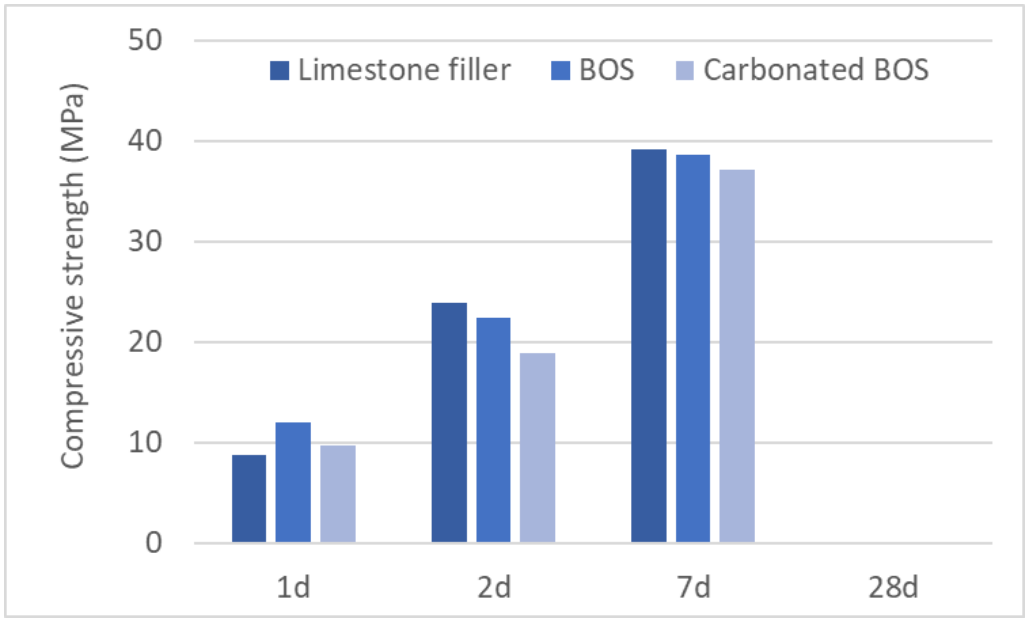
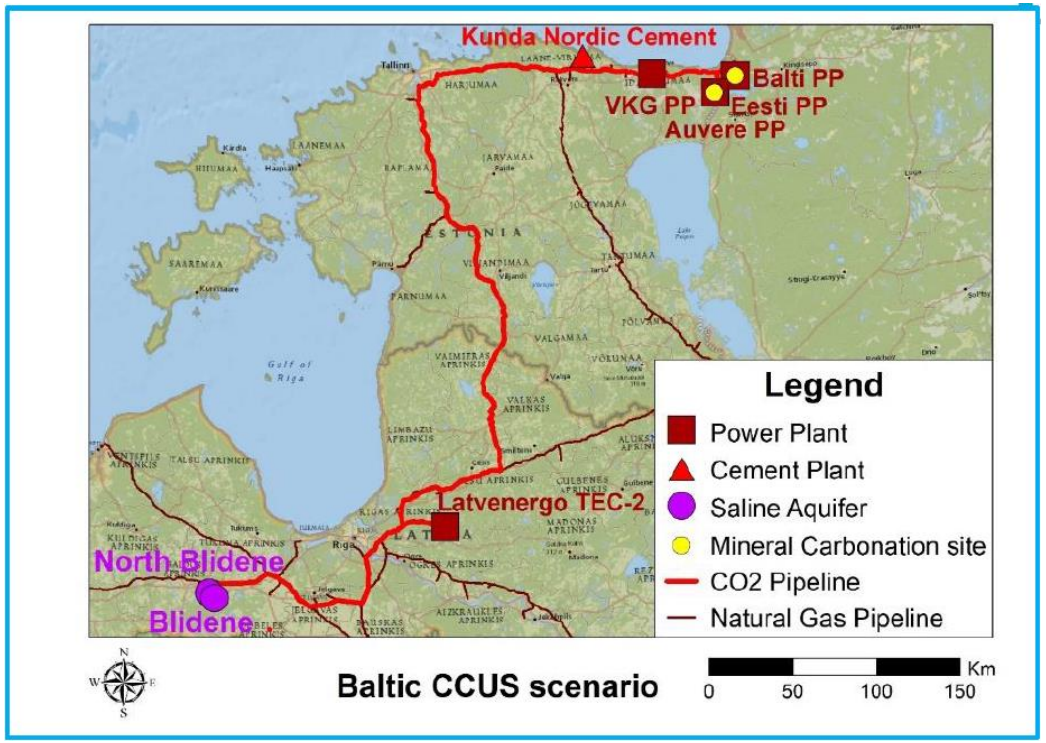
CO_2 mineralization tests

- On site mineralization tests of Estonian Burnt Oil Shale (BOS) (~10% wt. $Ca(OH)_2$) → up to 26 g_{CO2}/kg_{BOS} achieved (vs. 50 g_{CO2}/kg_{BOS} in lab tests)
- Use of carbonated BOS filler involves some loss of flexural and compressive strength and workability with respect to limestone filler.



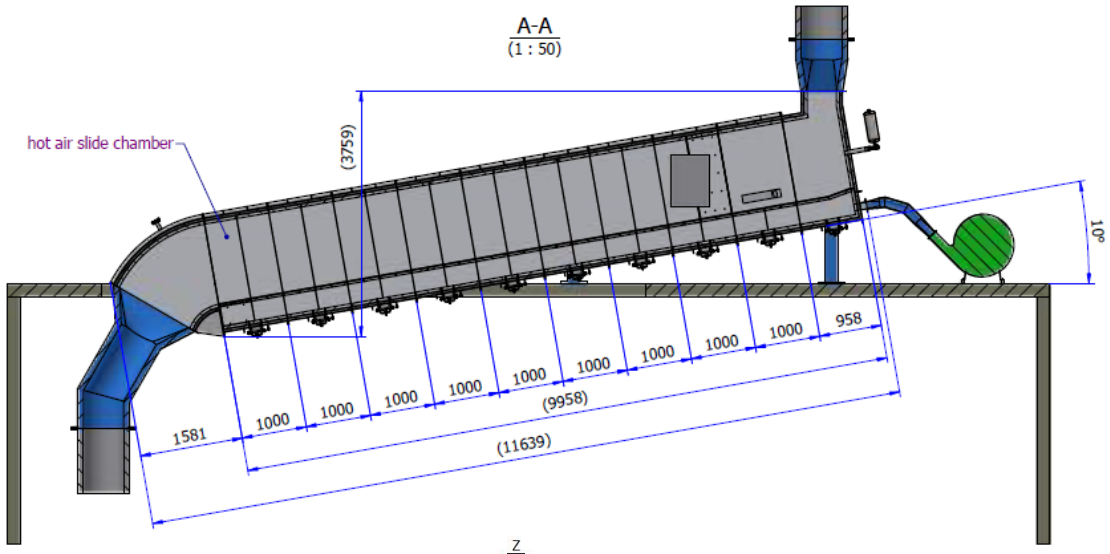
CO_2 storage

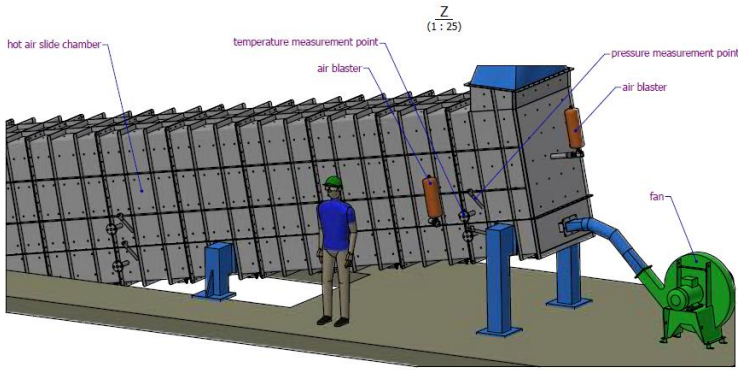
- Mineralization is a promising option, but CO_2 generated from a cement plant is such that most of it will need to be geologically stored.
- The CCS value chain in Europe is planned to develop quickly in the next few years in several countries (Norway, UK, Denmark, the Netherlands, Belgium, France, Bulgaria) and will hopefully develop in other EU countries (e.g. Italy, Greece and others).
- Among others, a Baltic CCUS scenario has been assessed combining CCS and mineralization of oil shale ash, to avoid the emission of 6.8 Mt_{CO2}/y.

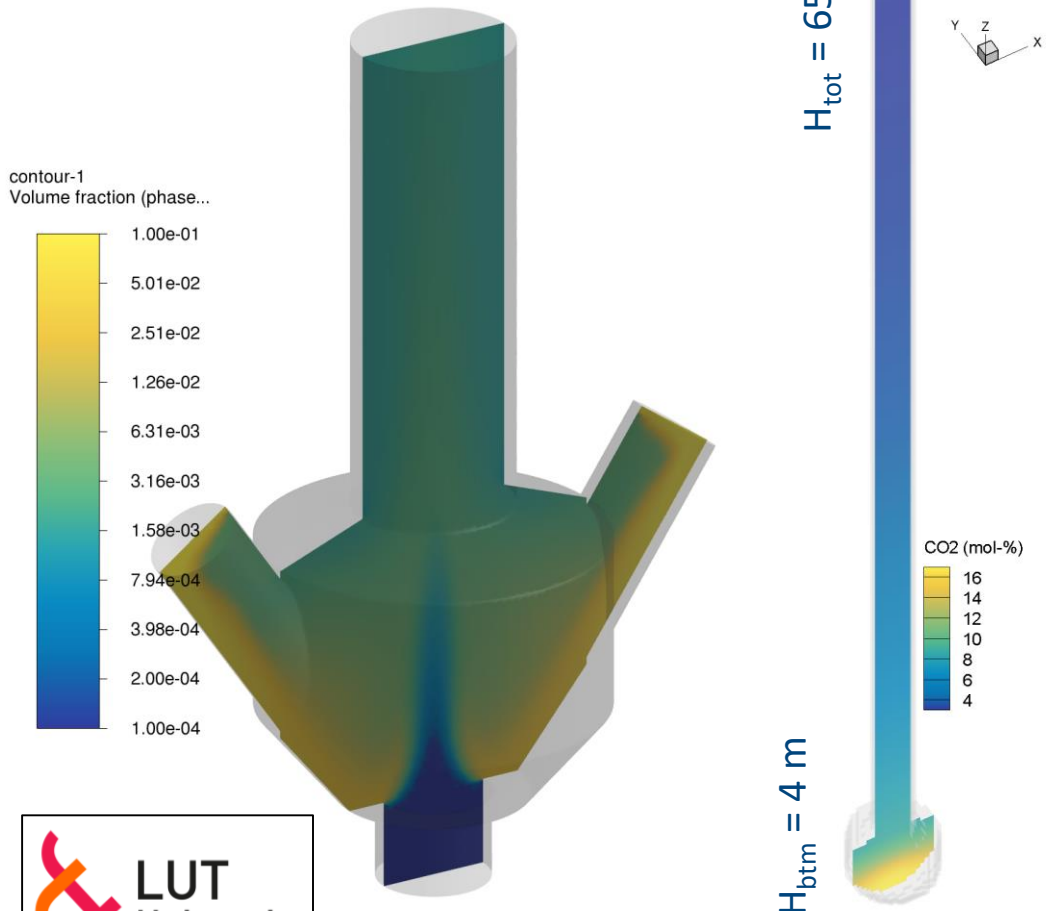


Scale-up study

- Novel CaL component design proposed for the scale up:
  - “Air slide” sorbent cooler (*IKN design*)
  - “Short” updraft carbonator (*LUT-IKN design*)

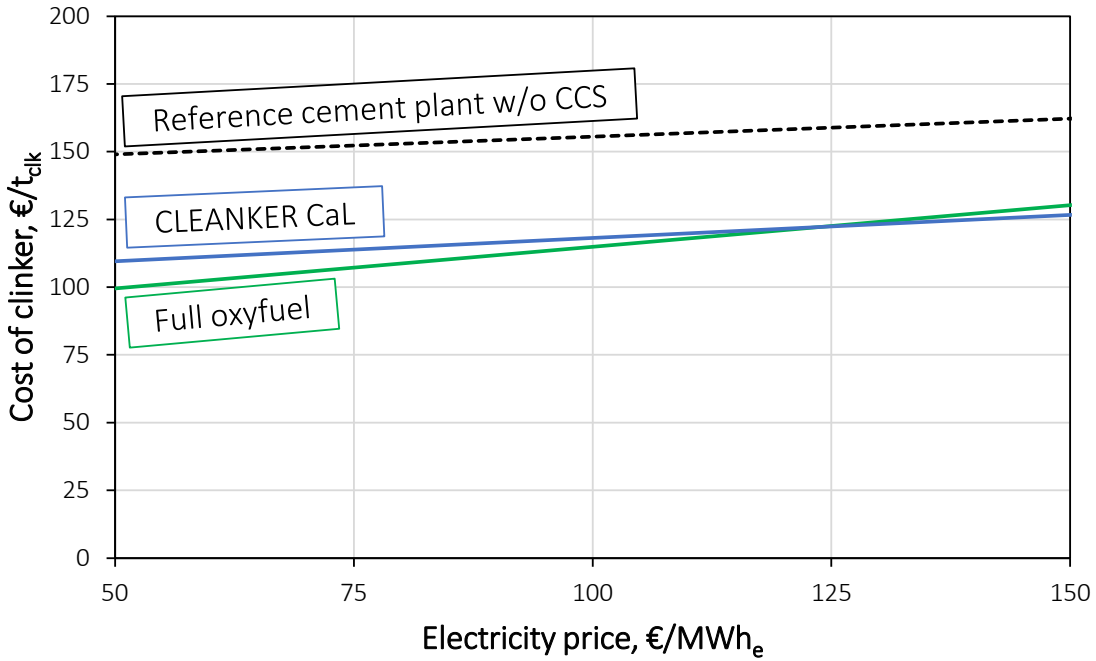


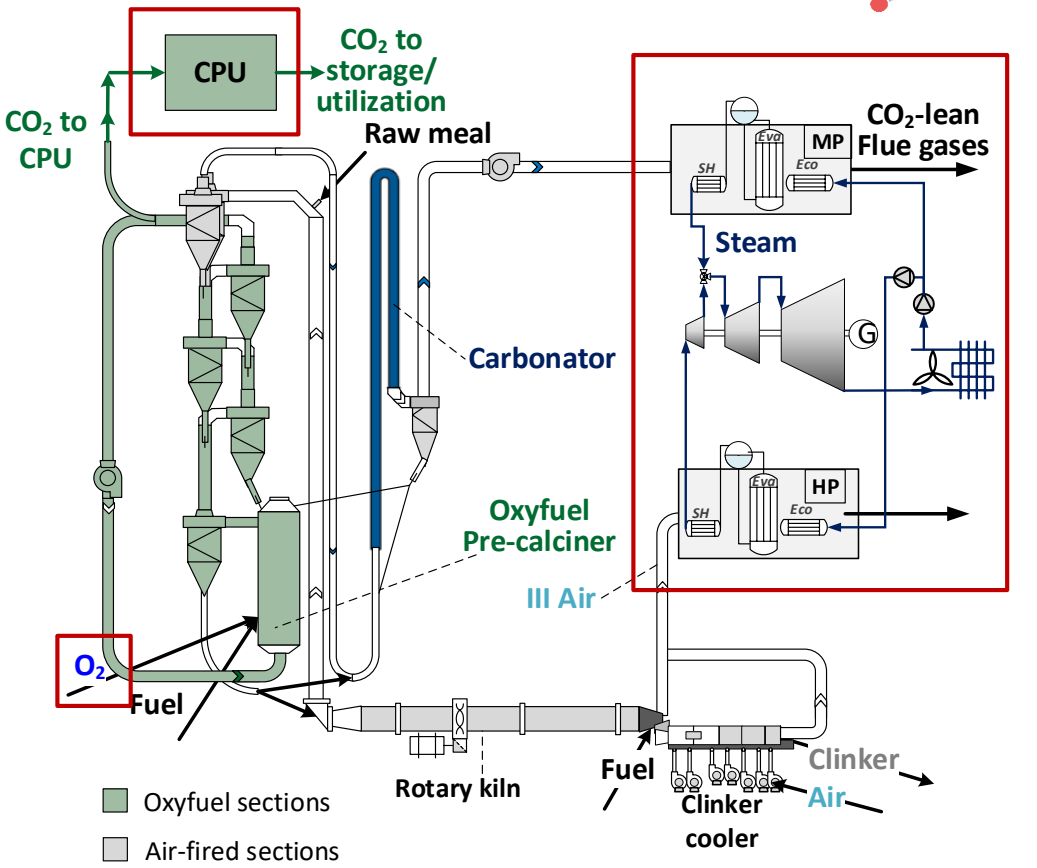




Integrated CaL process

- CaL involves a significant increase in fuel consumption (up to +60%)
- CaL is capital-intensive, mainly due to ASU, CPU & steam cycle Capex, with competitive cost of CO_2 avoided of 40-65 €/t.
- The self-production of low-carbon electricity from low-cost alternative fuels will be economically competitive with the supply of baseload renewable electricity from PV and Wind (plus batteries / other storage media)





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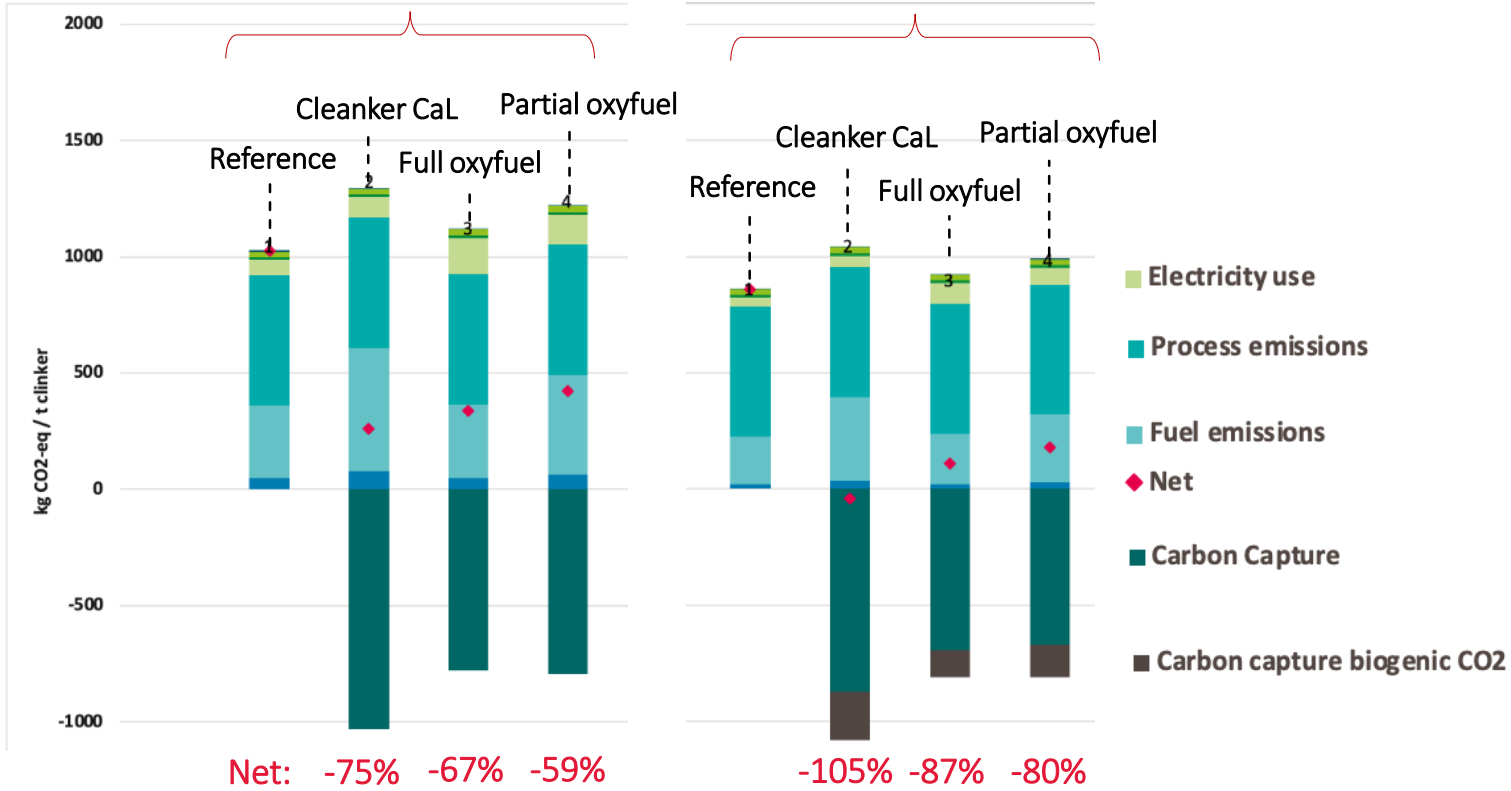
Negative emissions

- Moreover, the use of alternative fuels with CCS allows achieving near-zero / negative CO_2 emissions on LCA basis

Baseline scenario
- coal
- 40% fossil power generation

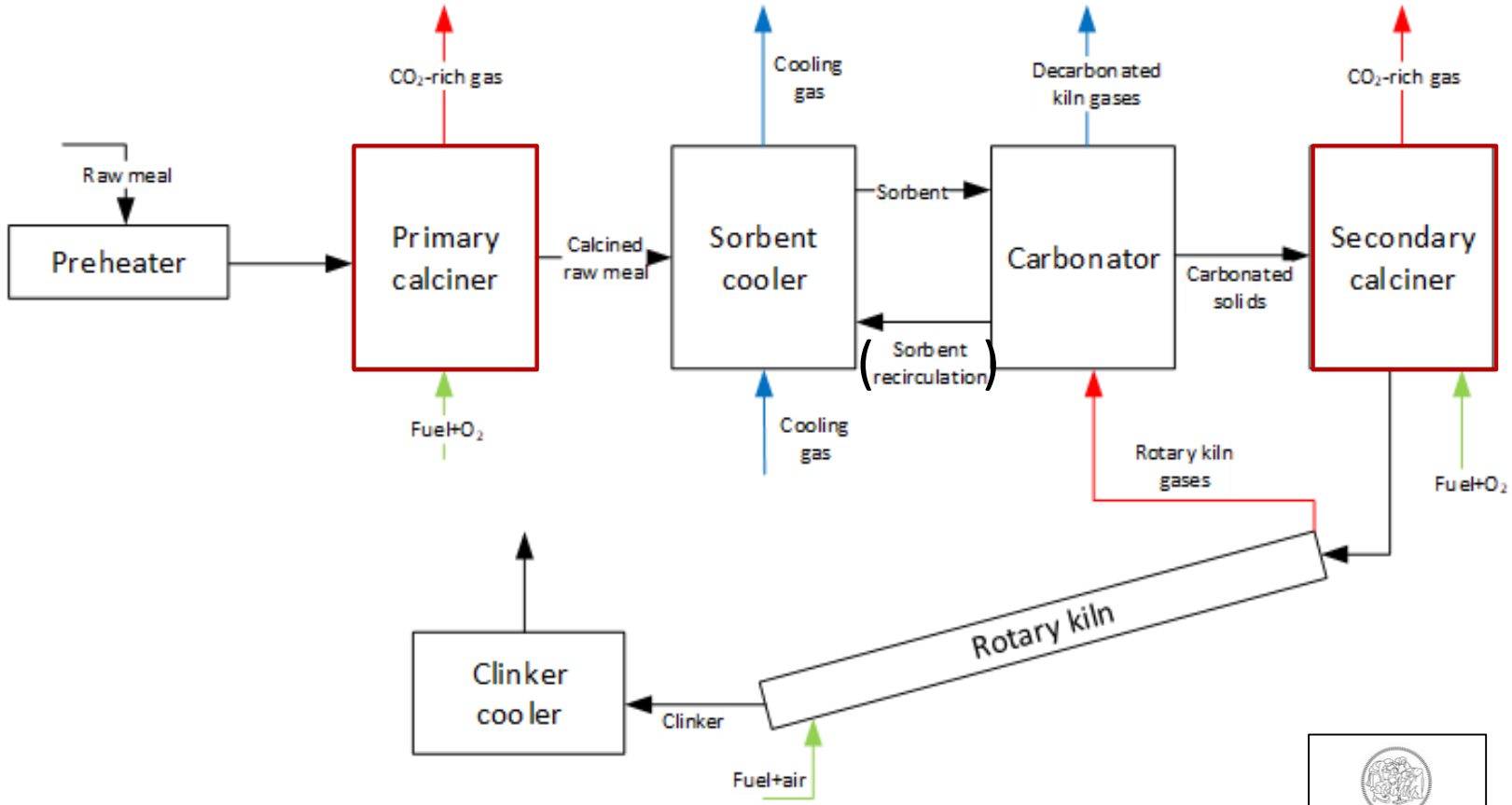
2030 scenario
- 60% RDF (32% biogenic carbon) / 40% coal mixture
- 36% fossil power generation



Dual-calciner CaL (DuCaL) process

Dual calciner configuration (*patent pending*):

- Once-through: improved process controllability
- High sorbent activity (1 single calcination experienced) and sufficient availability ($F_{Ca}/F_{CO2} \approx 4$)
- Possibly higher reliability of clinker production (disconnection of carbonator and secondary calciner)



PCT patent filed WO/2023/002430
Matteo C. Romano, Edoardo De Lena, Maurizio Spinelli: ASSEMBLY FOR REDUCING CO_2 EMISSION IN PLANTS FOR CLINKER PRODUCTION
https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2023002430&_cid=P20-LEVPST-80572-1

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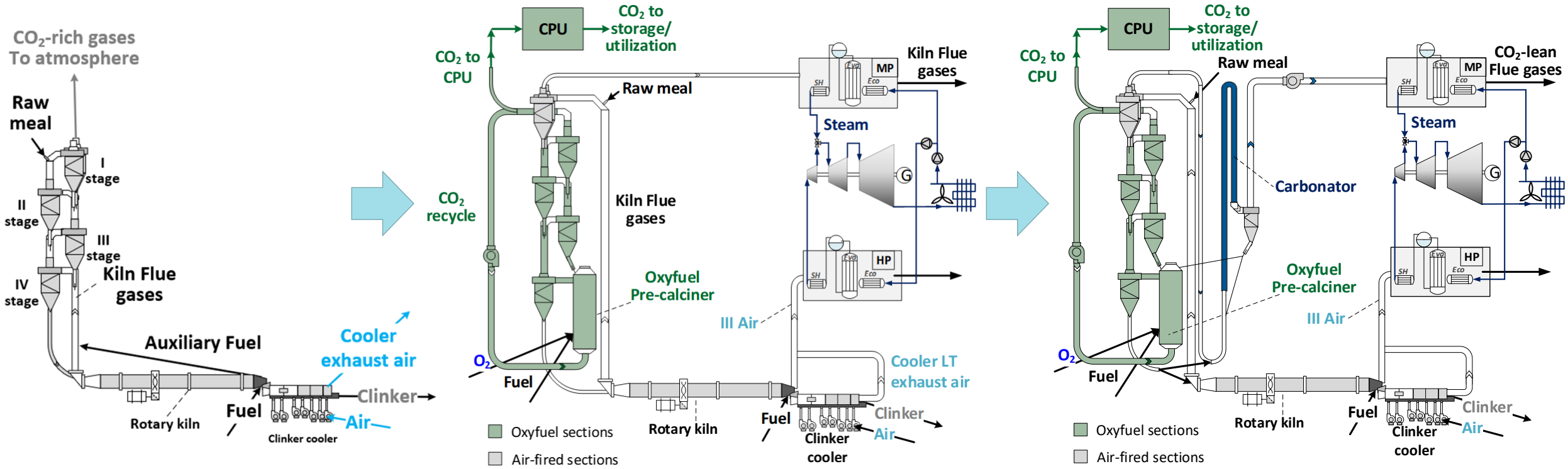
The future of the Cleanker CaL technology

- **2025-2030:** 1) Install commercial partial oxyfuel plants; 2) scale-up Cleanker CaL to TRL8
- **2030-2035:** 3) Upgrade the partial-oxyfuel plant to a negative emission Cleanker CaL



Conventional cement plant *2025-2030: Partial oxyfuel retrofit* *2030+: Integrated CaL retrofit*

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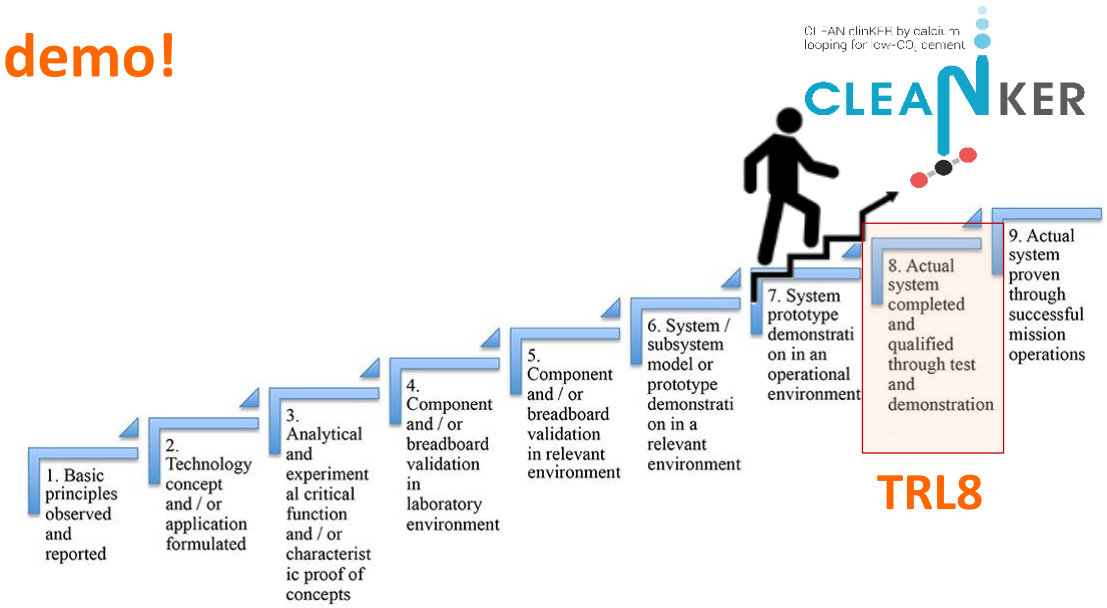
The future of the Cleanker CaL technology

Not easy to compete with more mature technologies, but CaL has some significant **advantages** :

- materials and components familiar to cement industry (no new chemicals or exotic component).
- no impact on the rotary kiln and the clinker cooler
- self production of baseload low-carbon power
- achievement of overall negative emissions with biogenic AF

It's time for a TRL8 demo!



Thanks for your attention!

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www.cleanker.eu

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