6/10/2021

Workshop on the Development of Efficient CO_2 Capture Technologies for Cement and Lime Industries

Integrated Calcium Looping Technology for the Cement Industry and Status of CLEANKER Pilot Plant

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Buzzi Unicem

The CLEANKER project – Primary project objectives

The ultimate objective of CLEANKER is advancing the integrated Calcium-Looping (CaL) process for CO_2 capture in cement plants.

This fundamental objective will be achieved by pursuing the following primary targets:

- **Demonstrate the integrated Calcium-Looping process at TRL 7, in a new demo system connected to the operating cement burning line of the Vernasca 1.300.000 ton/y cement plant, operated by Buzzi Unicem in Italy.**
- **Demonstrate the technical-economic feasibility of the integrated CaL process in retrofitted large scale cement plants through process modelling and scale-up study.**
- **Demonstrate the storage of the CO_2 captured from the CaL demo system, through mineralization of inorganic material in a pilot reactor of 100 litres to be built in Vernasca, next to the CaL demo system.**

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The CLEANKER project – The consortium

Starting date: October 1st 2017

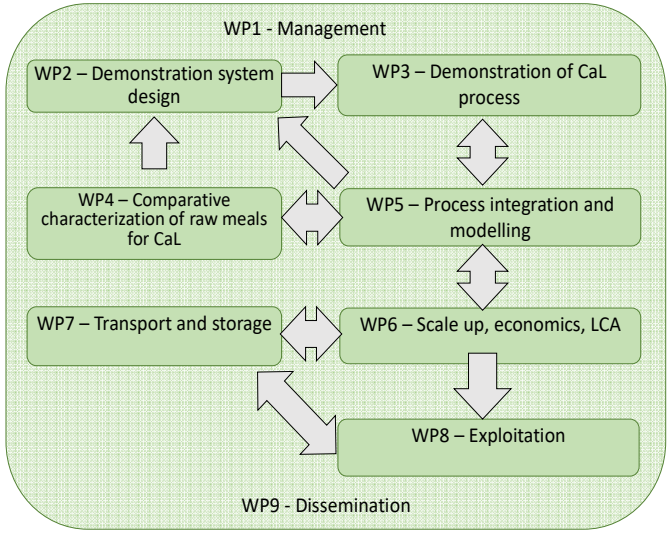
Duration: 4 years and half

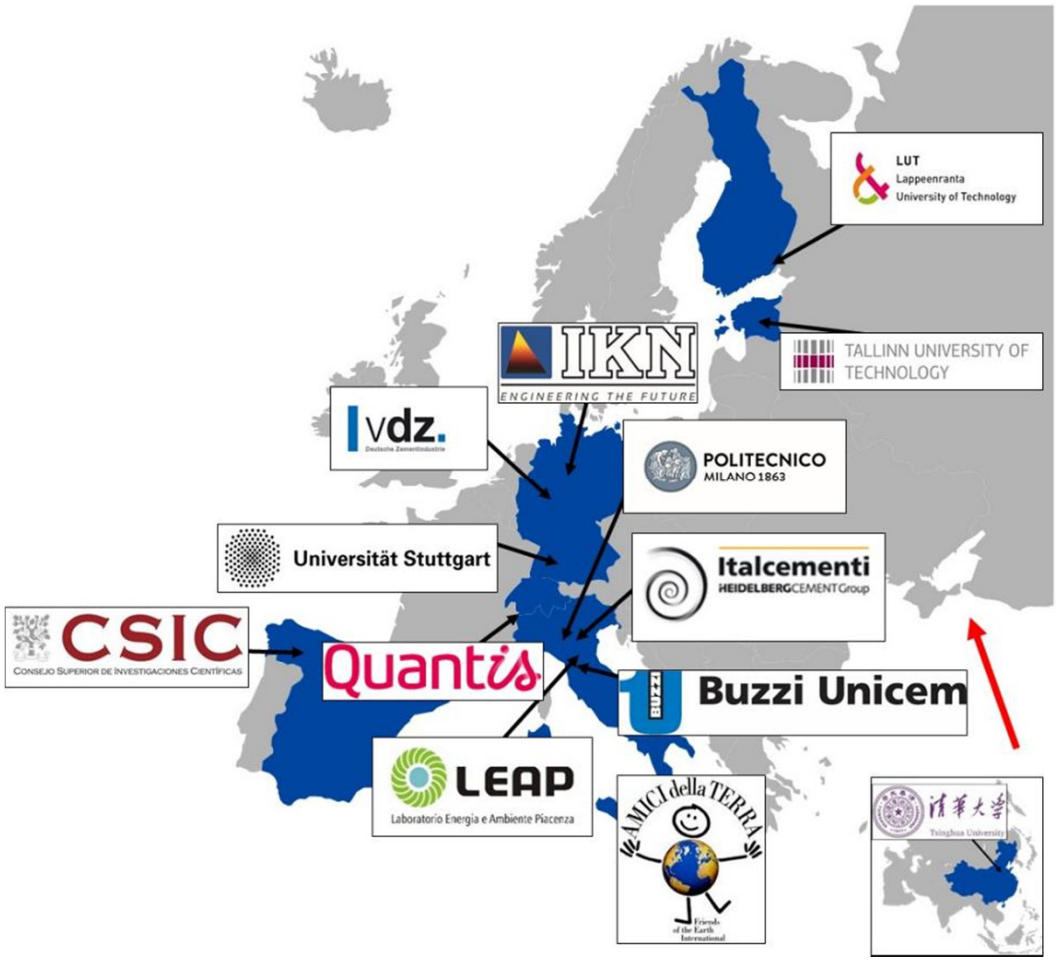
Total budget: € 9.237.851,25

EU co-financing: € 8.972.201,25

Chinese governement funding: 265.650 €

Partner: 13 from 5 EU member states + Switzerland and China





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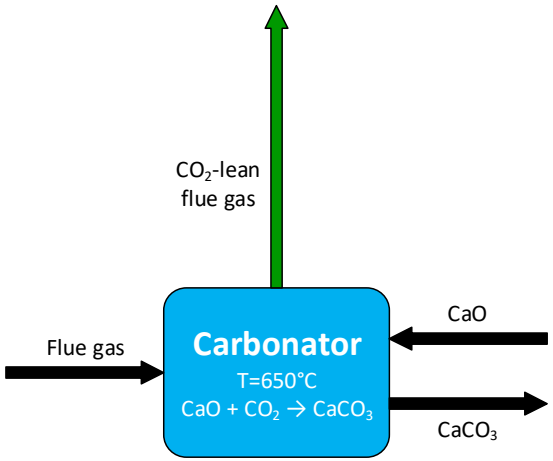
Calcium Looping concept



- **Flue gases enter the carbonator together with CaO, which acts as a CO_2 sorbent**
- **Carbonation reaction:**
  $CaO + CO_2 \rightarrow CaCO_3$ @ 600 – 650 °C
- **CO_2 is selectively captured** from the flue gas stream

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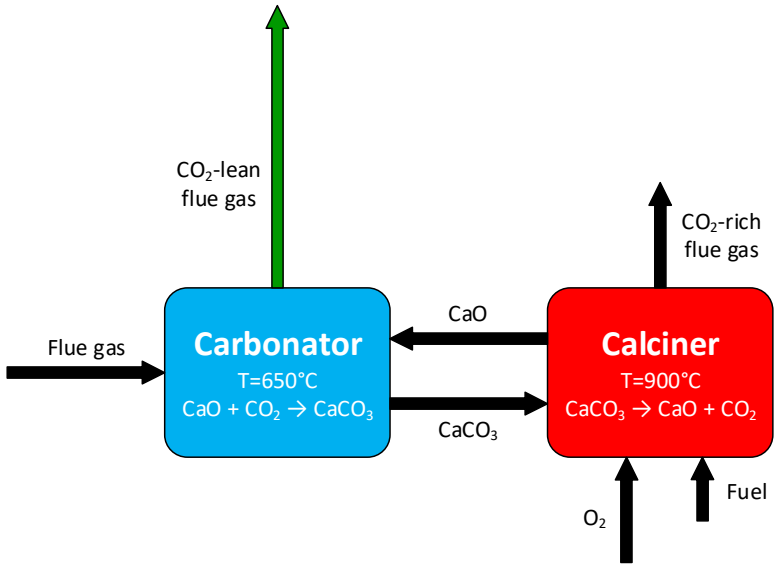
Calcium Looping concept



- **CaO is produced in the calciner, where the opposite reaction is performed and the captured CO_2 is released**
- **Calcination reaction:**
  $CaCO_3 \rightarrow CaO + CO_2$ @ 900°C
- **The necessary heat is provided by burning a fuel in pure oxygen**

→ Oxy-fuel combustion produces a CO_2–rich flue gas stream (theoretically, a CO_2 – H_2O binary mixture)

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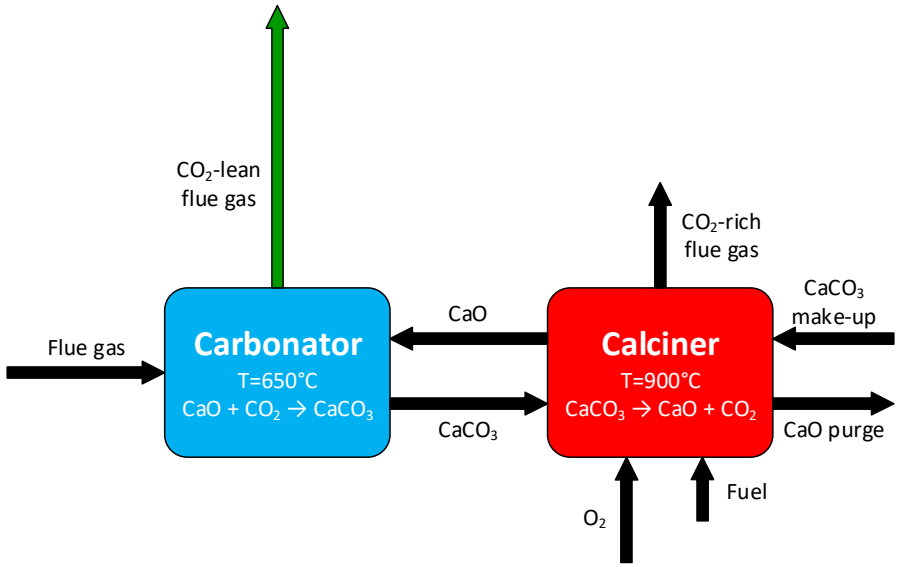
Calcium Looping concept



- **Continuous $CaCO_3$ make-up and CaO purge shall be guaranteed to the calciner**, in order to:
  - Prevent contaminant accumulation
  - Counteract CaO deactivation as a CO_2 sorbent

- **This is the Calcium Looping working principle → for real application some auxiliary units are needed**

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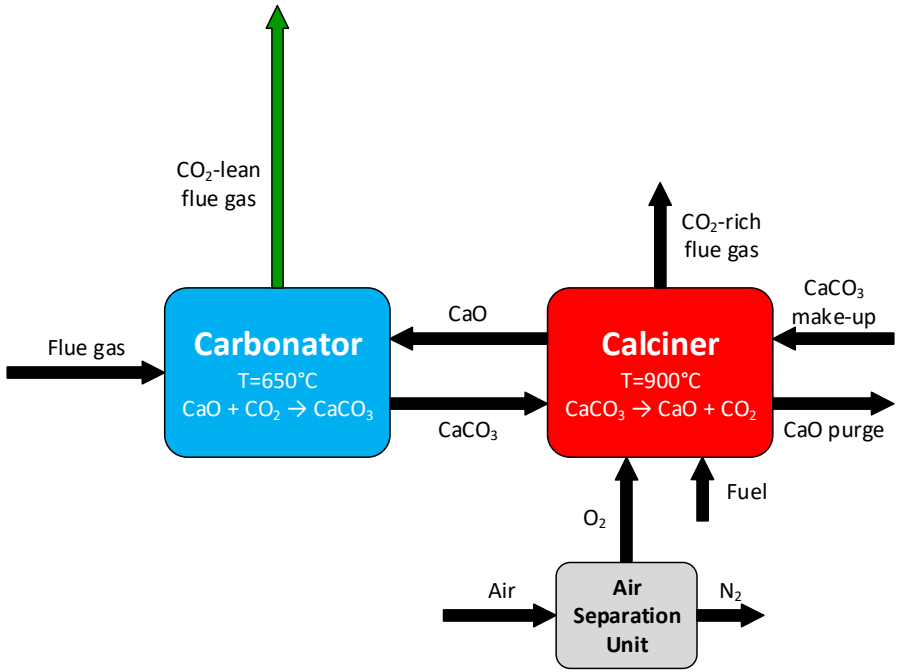
Calcium Looping concept – Auxiliary plants

- **An Air Separation Unit (ASU) is needed** to produce the pure oxygen needed by the calciner



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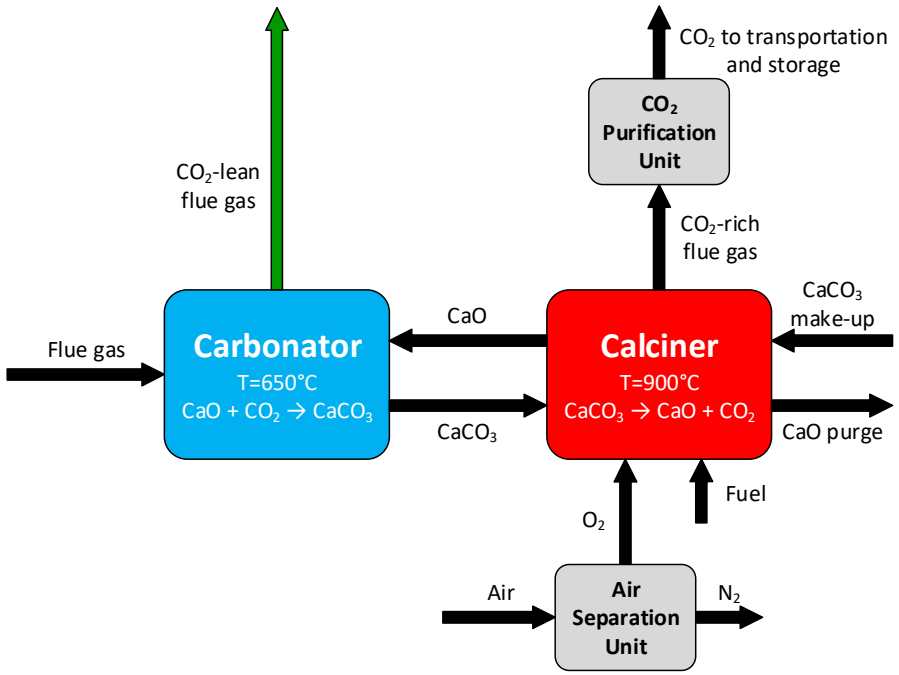
Calcium Looping concept – Auxiliary plants



- **The flue gas stream produced by a real oxyfuel combustion is not a CO_2 – H_2O binary mixture** (because of air leakages, ASU efficiency, actual fuel and sorbent composition…)

→ A CO_2 Purification Unit (CPU) is needed to remove oxygen, other non-condensable species and contaminants unwanted for CO_2 transportation/storage/utilization

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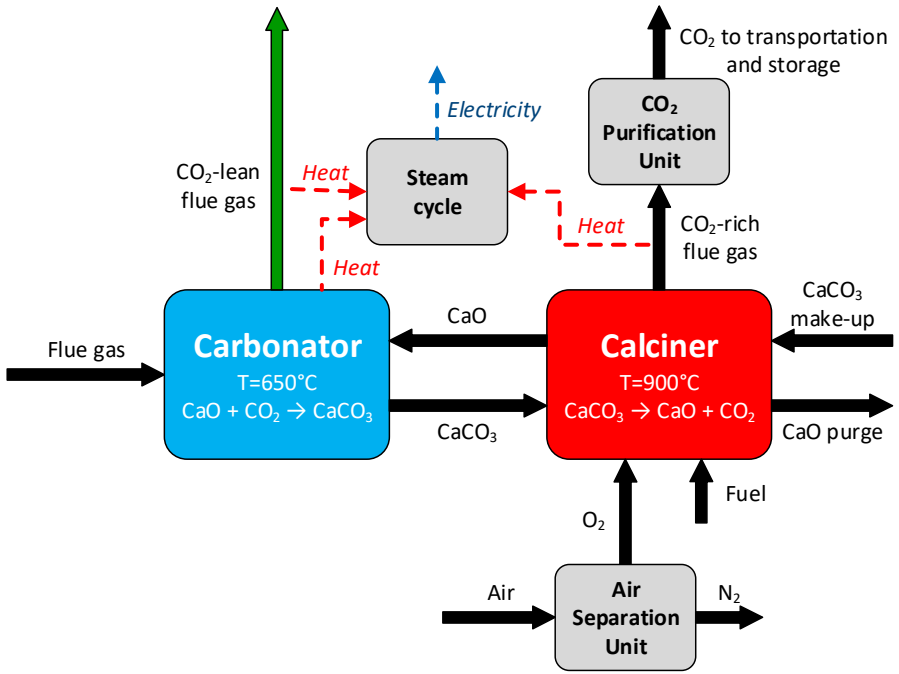
Calcium Looping concept – Auxiliary plants



- Given the **high temperatures** involved in the process, **heat can be efficiently recovered in a steam cycle to produce electricity**, thus decreasing the electricity consumption of the capture process

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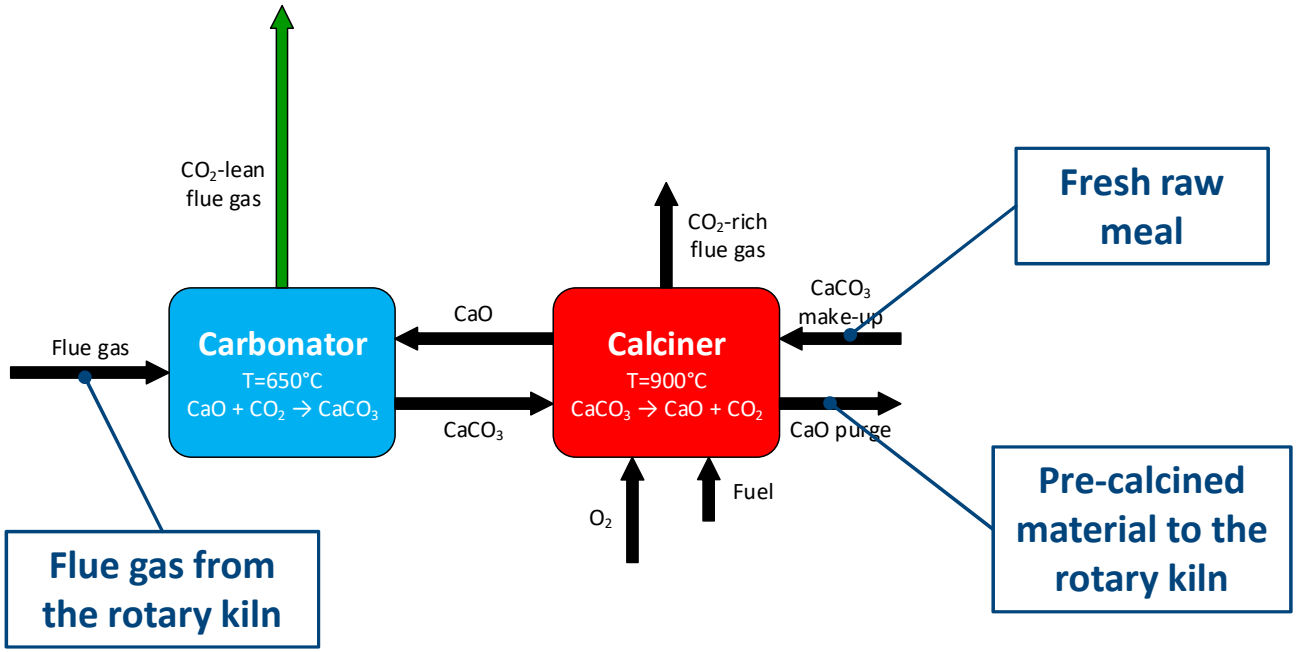
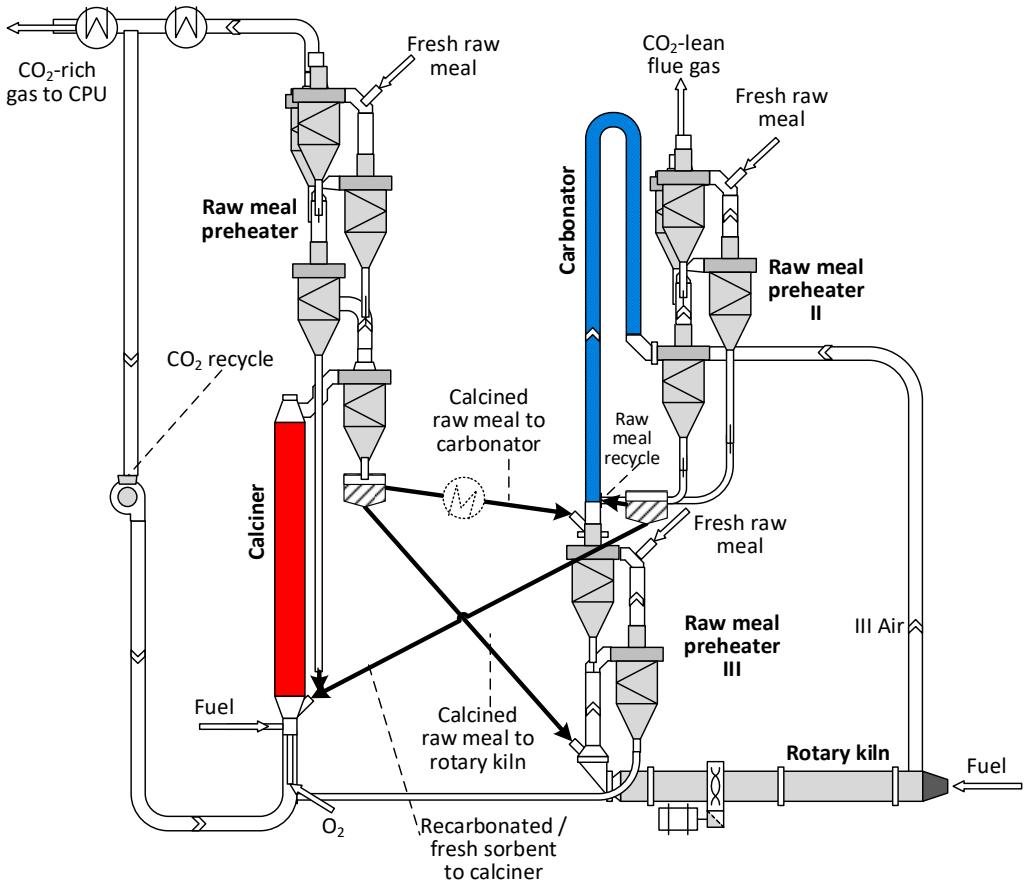
Calcium Looping in cement industry – Integrated configuration

- The CaL CO_2 capture process can be efficiently integrated in the clinker production



Calcium Looping in cement industry – Integrated configuration



- **CaL Calciner** coincides with the **cement kiln pre-calciner,** but it operates in **oxyfuel**
  → **Combustion gas is very rich in CO_2** (no N_2 dilution)

- **Pre-calcined raw meal is split** to be fed**:**
  - **To the rotary kiln**, as in conventional plants
  - **To the Carbonator**, where it acts as **CO_2 sorbent** to selectively capture the **CO_2 contained in kiln flue gases**

    → The **$CaCO_3$** leaving the **Carbonator** is then **recycled to the Calciner**, where the captured CO_2 is released in the CO_2 -rich stream

    → The **gas stream** leaving the **Carbonator** is **virtually CO_2 -free**

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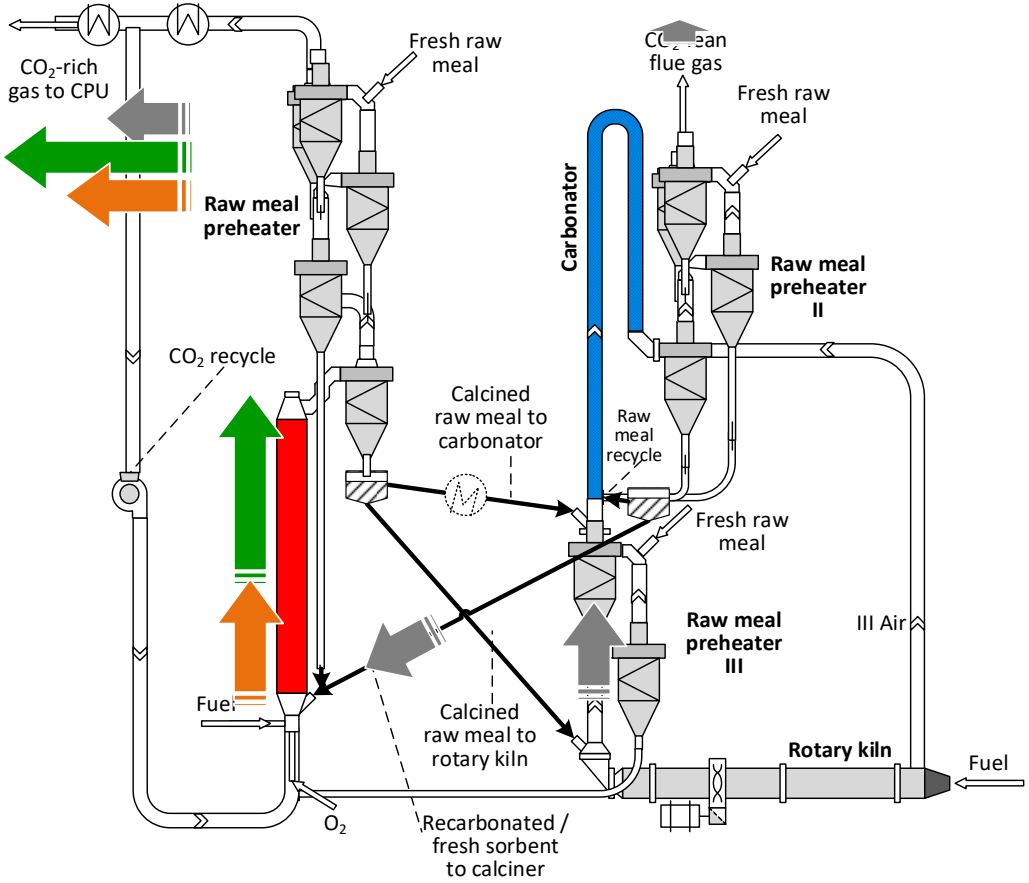
Calcium Looping in cement industry – Integrated configuration



The integrated Calcium Looping process captures:

- **All the CO_2 generated in the calciner**
- **The CO_2 captured by the carbonator**
  → This value depends on **carbonator CO_2 capture efficiency**

- **Carbonator efficiency ~80%**
  → global capture efficiency >90%

CO_2 generated from :

- Fuel combustion in the calciner
- Fuel combustion in the rotary kiln
- Raw meal calcination

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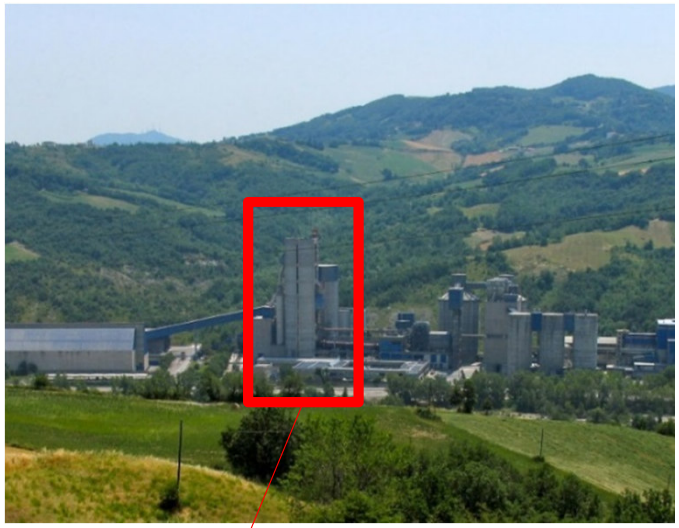
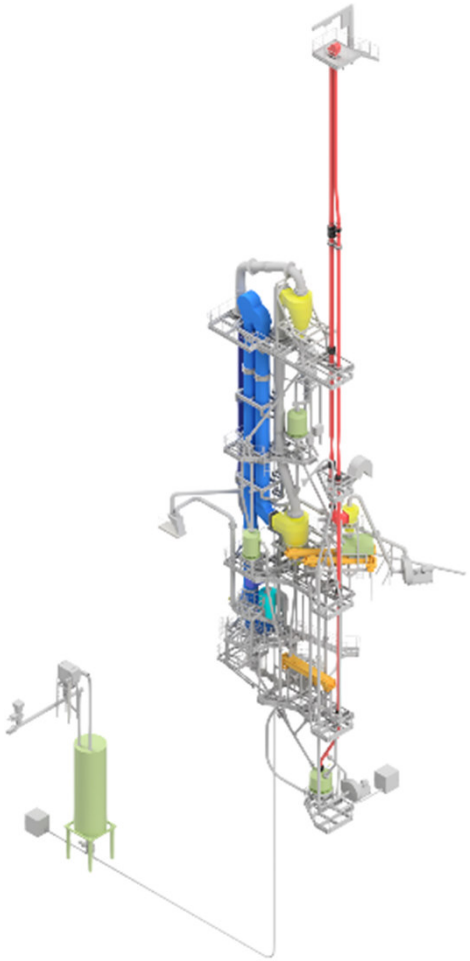
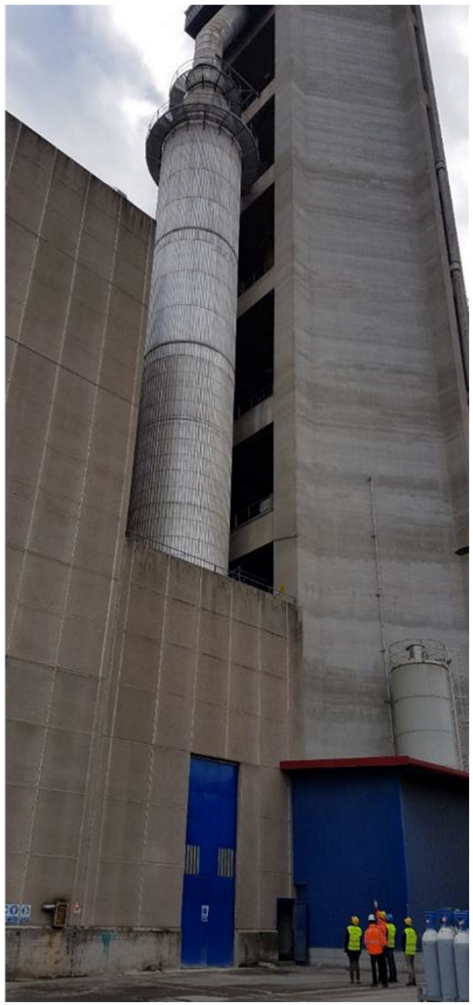
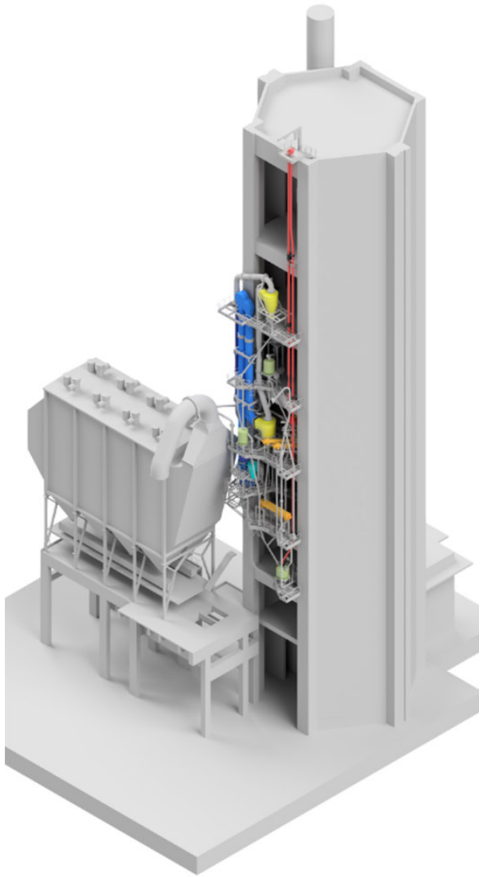
The CLEANKER demo system



Preheater tower







The CLEANKER demo system

The CLEANKER demo system – The Carbonator

- Entrained flow reactor in stainless steel
- Gooseneck shape: riser and downcomer, for a total length ~ 105 m
- Diameter: 250 – 350 mm

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The CLEANKER demo system – The oxyfuel Calciner

- Two burners, heavy oil as fuel
- Several oxygen injection points for a better control of temperature profile
- A water-cooled screw heat exchanger cools the material produced by the Calciner to the temperature required by the Carbonator

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Experimental campaigns

- Nine experimental campaigns have been scheduled:
  - 5 short tests of three days each
  - 4 long tests of one week each
- The aim of the short tests is to identify the most attractive operating conditions for the longer test runs

→ Particular attention will be given to the analysis of the governing parameters of the CaL process:

- Oxidizer for the calcination process: Air/Oxygen
- Calciner outlet temperature
- Type of CO_2 sorbent, i.e. different raw meals
- Gas flow rate at carbonator inlet
- Solid to gas ratio in the carbonator
- Solids temperature at carbonator inlet

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Acknowledgments

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