An ECCSEL ERIC project

CLEAN clinKER by calcium looping for low-CO_2 cement

CLEANKER

ECCSELERATE – Webinar, 16th June2021
«Chemical looping and gas switching combustion”

Calcium Looping technology demonstration in industrial environment: CLEANKER

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LEAP s.c.a r.l.

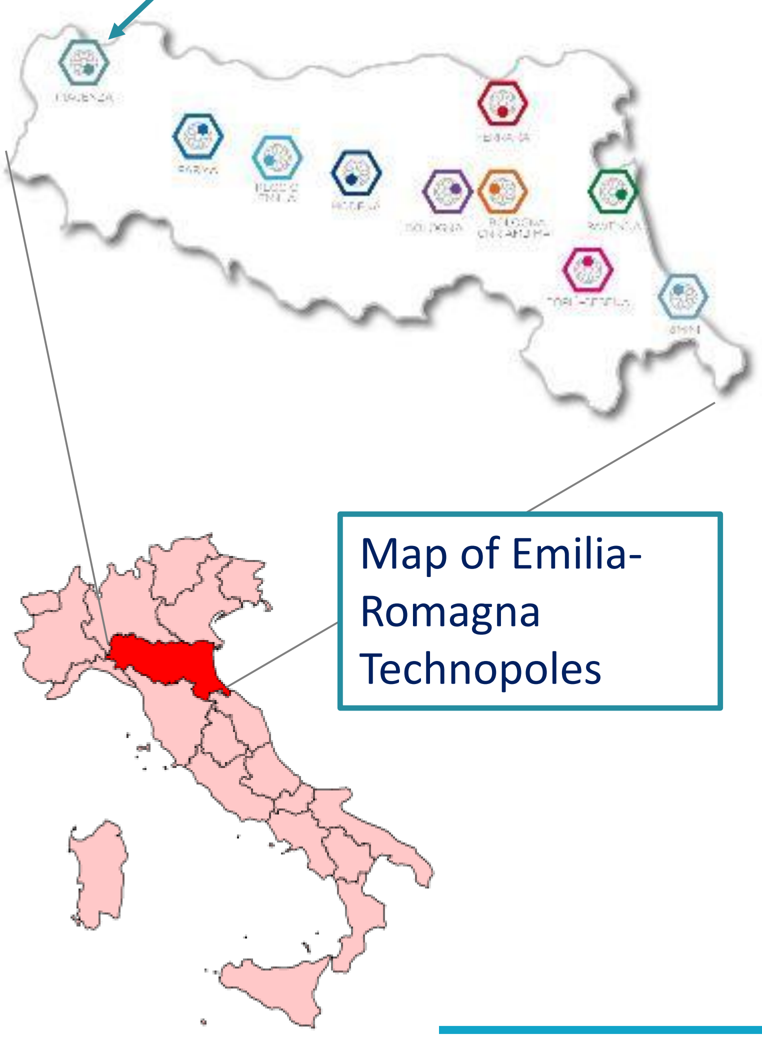
Summary

- LEAP and CO2_box

- Main technologies for CO_2 capture in cement plants:
    - Post-combustion solvent systems
    - Oxyfuel
    - Calcium looping

- CLEANKER project
    - Project objectives
    - The consortium
    - CaL integrated configuration
    - CLEANKER demo system
    - CLEANKER project timeline

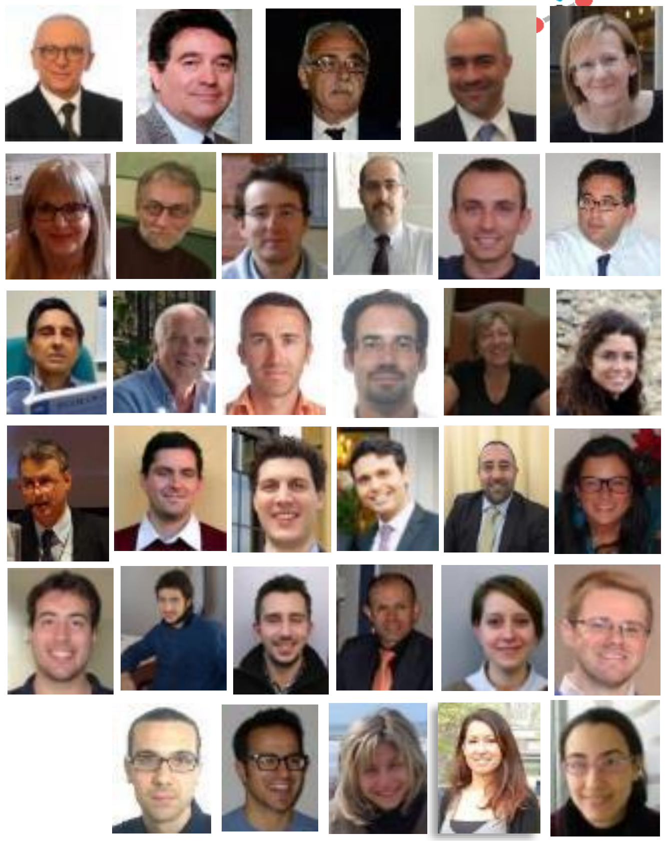
LEAP and CO2_box



Map of Emilia-Romagna Technopoles

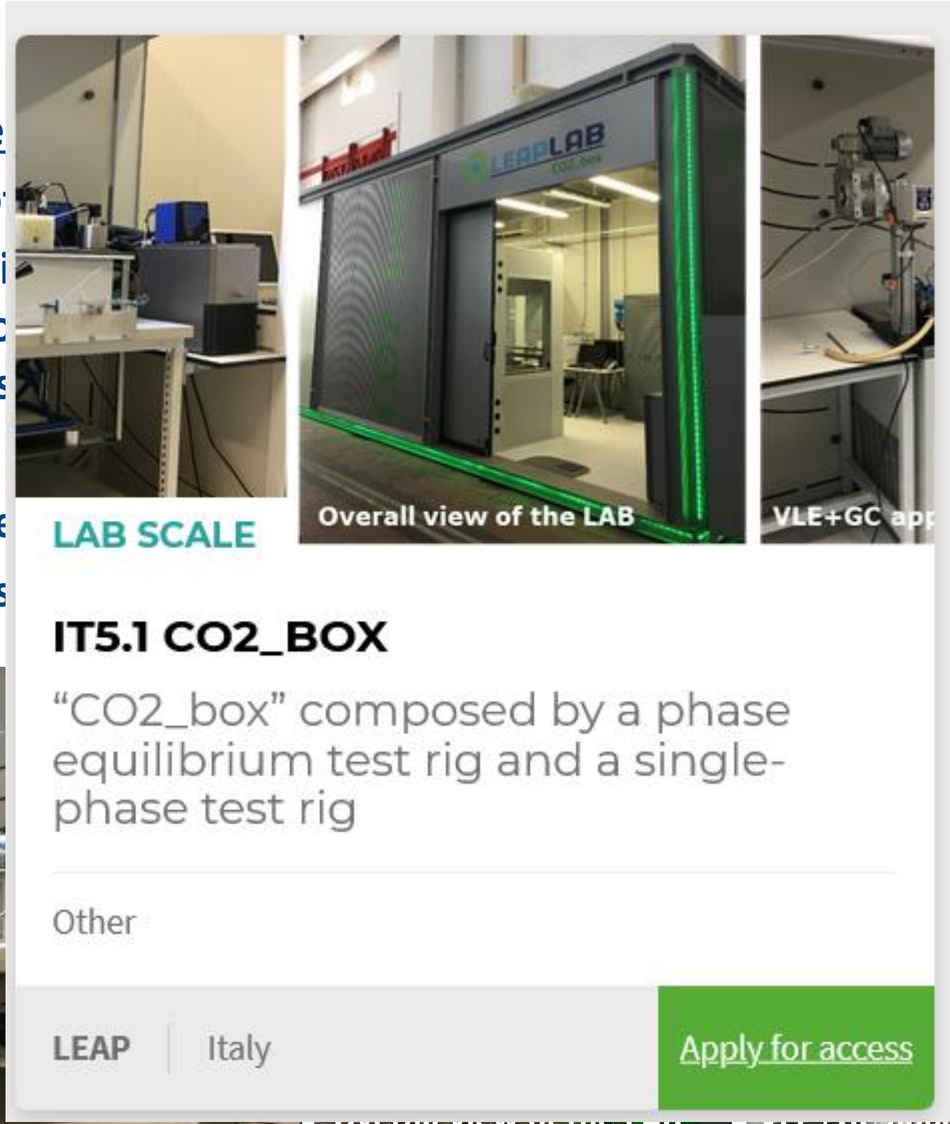
LEAP stands for Laboratorio Energia & Ambiente Piacenza (Laboratory for Energy and the Environment – Piacenza). LEAP is a limited liability consortium founded in Piacenza in May 2005 to accomplish a project of the Piacenza campus of Politecnico di Milano.

- Research main lines:
  1. material and energy recovery from waste, residues and biomass
  2. fossil fuel technologies and CO2 capture and conversion
  3. renewable energies and energy efficiency
  4. gaseous emissions, fine particles and air quality



LEAP and CO2_box

- <u>Consulting and technical service</u>
  - modeling and simulations o
  - on-site experimental activiti … ion chamber of WTE plants and industrial boilers through suction pyro … mplings both in conveyed flows and in atmosphere, measurements … veyed flows
- Experimental Laboratories:
  - heat_box: test bench for the … W of thermal power
  - CO2_box: test rig for the ass … O2 based mixtures



CO_2_box

- In the CO_2_box lab, LEAP carries out experimental campaigns to measure single-phase Pressure-temperature-density properties and Vapor-Liquid-Equilibria for CO_2 mixtures
- Two test benches, with different capabilities, are available: P-v-T and VLE apparatus

P-v-T apparatus		VLE apparatus	
p [MPa]	0.1 ÷ 20	p [MPa]	0.1 ÷ 19.9
T [°C]	-10 ÷ 150	T [°C]	-60 ÷ 200

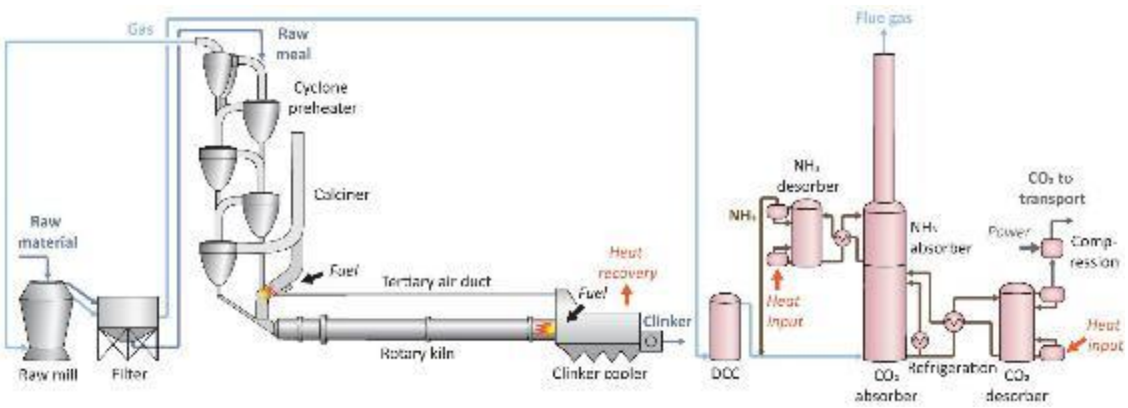
CO2_box capabilities	
CO2 mixtures (pre-combustion)	CO2 + (N2, H2, CO, H2S)
CO2 mixtures (oxy-fuel)	CO2 + (Ar, O2, N2, SO2)
ORC working fluids	Toluene, Benzene, p-xilene (aromatics HC)
	MM, MM/MDM/MD2M (Siloxanes and their mixtures)
	Butane, Pentane (HC with linear chain)
	Exafluorobenzene (Perfluorinated aromatics HC)
Other fluids for chemical and process industry	Refrigerants and their mixtures

SCARABEUS

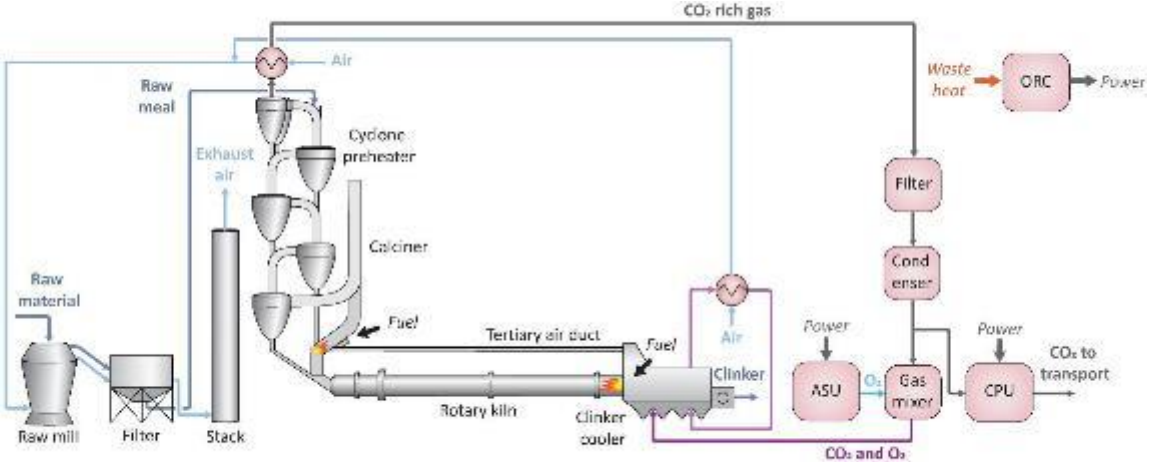
- Supercritical CARbon dioxide/Alternative fluids Blends for Efficiency Upgrade of Solar power plant - GA: 814985
- www.scarabeusproject.eu

Main technologies for CO_2 capture in cement plants

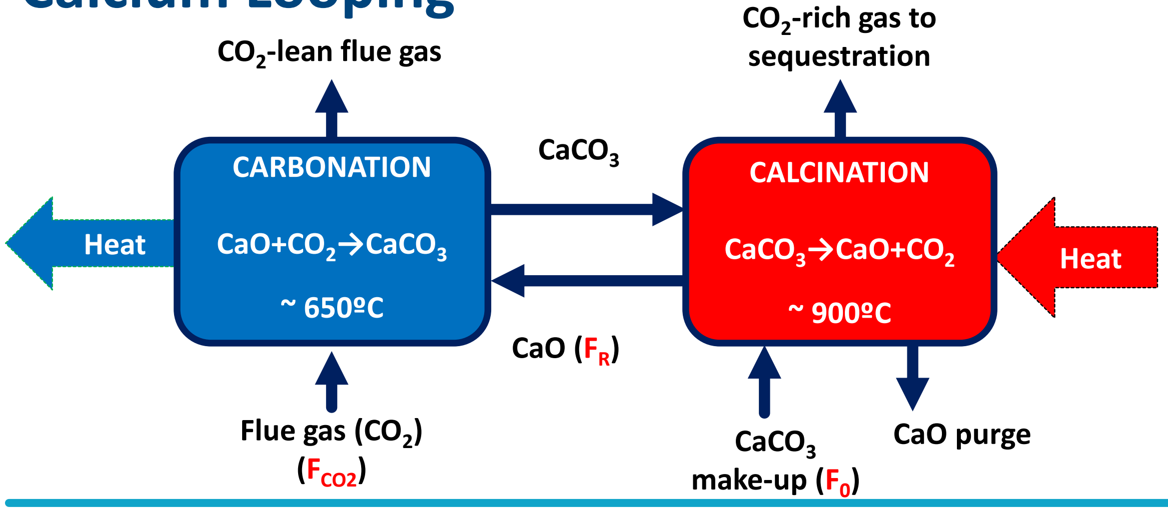
Post-combustion capture by solvents



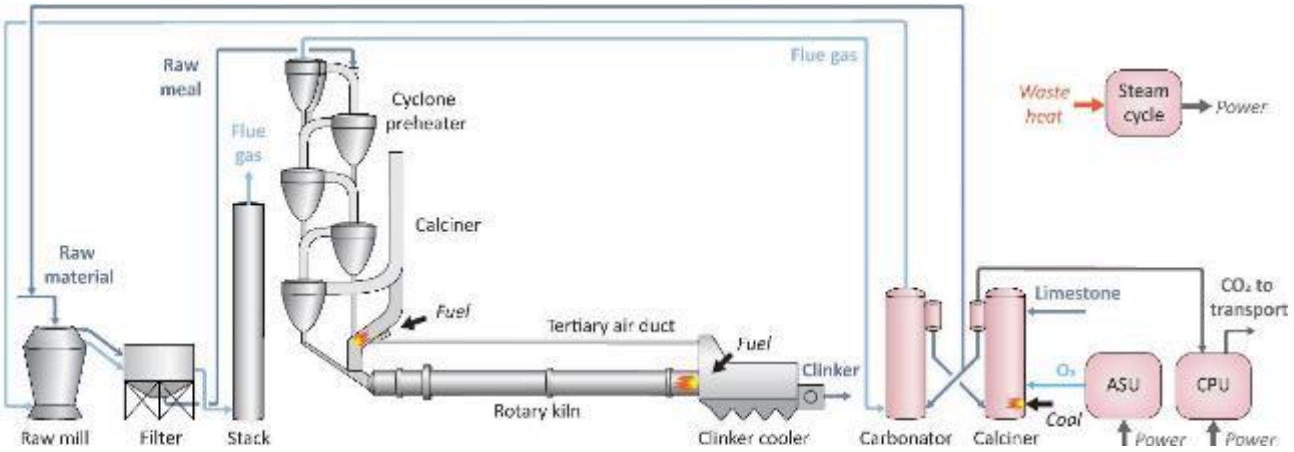
Oxyfuel combustion



Calcium Looping



Calcium Looping – tail end



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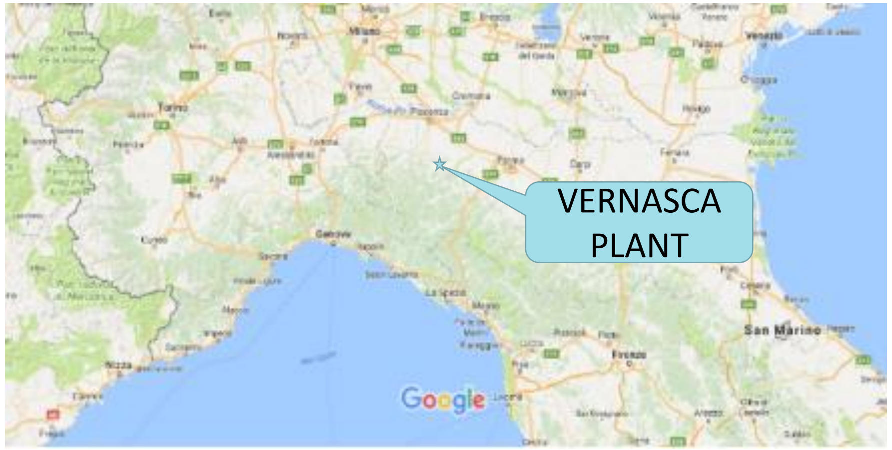
Primary project objectives

The ultimate objective of CLEANKER is advancing the integrated Calcium-looping process for CO_2 capture in cement plants.



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

- **Demonstrate the integrated CaL 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 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.**

Co-funded by the Horizon 2020 Framework Programme of the European Union

The consortium

Starting date: October 1st 2017

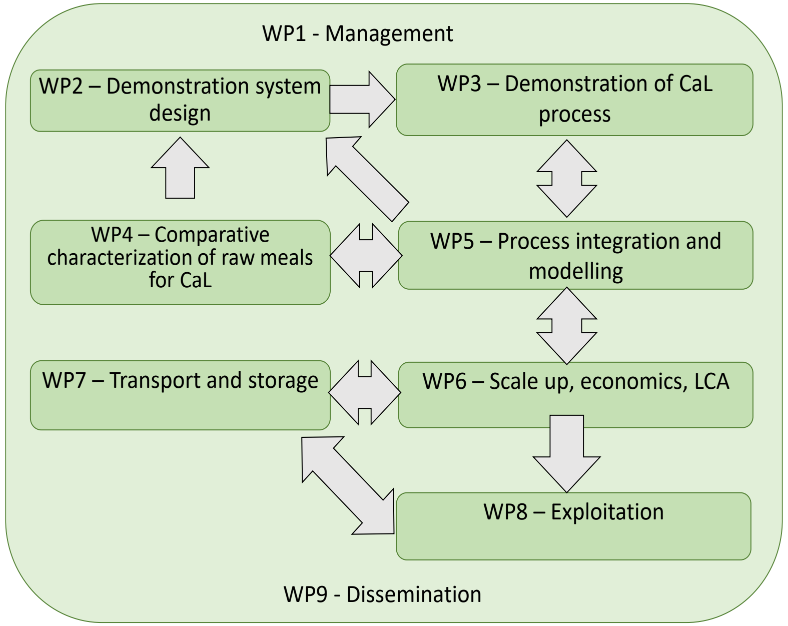
Duration: 4 years

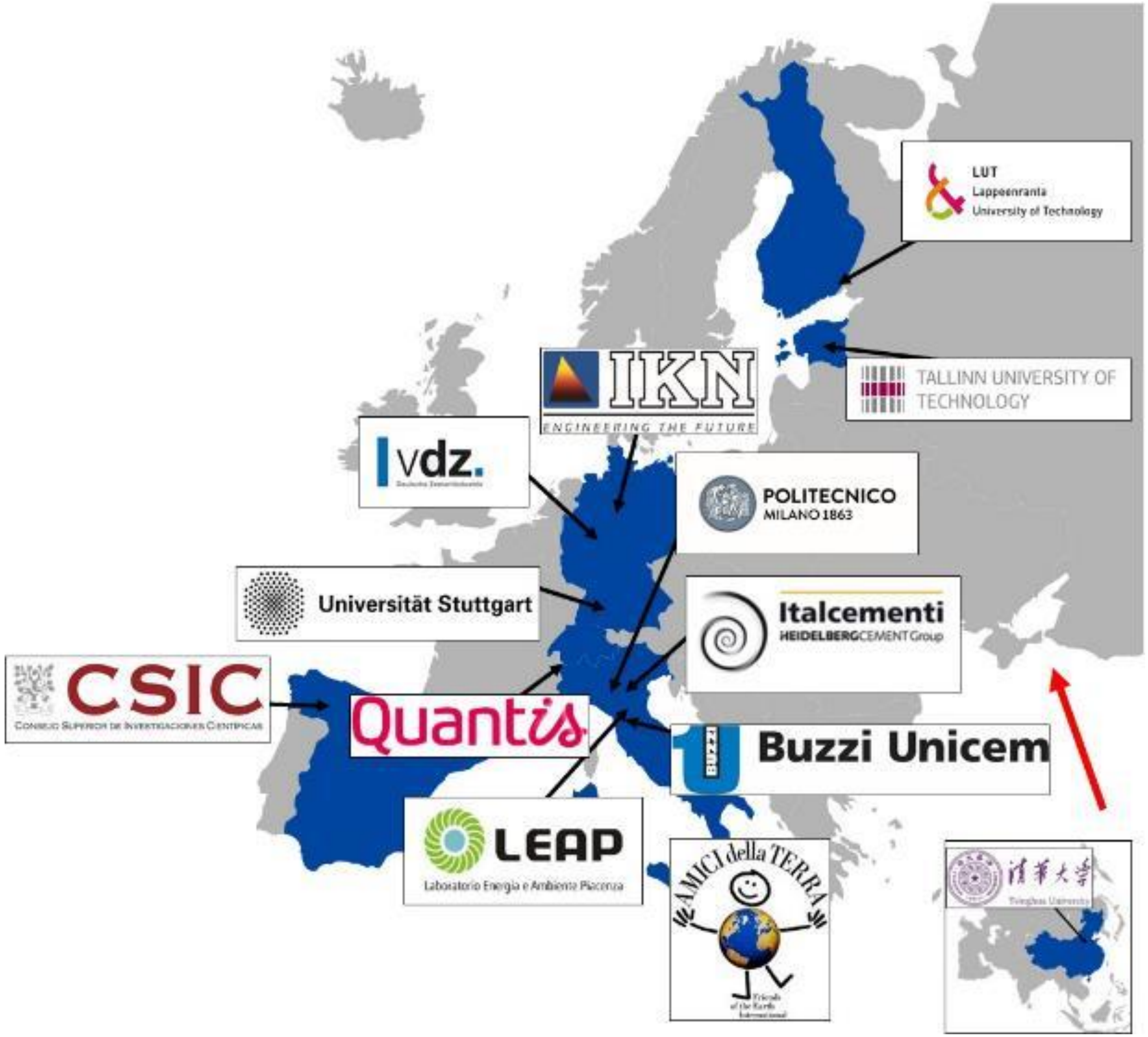
Total budget: € 9.237.851,25

UE co-financing: € 8.972.201,25

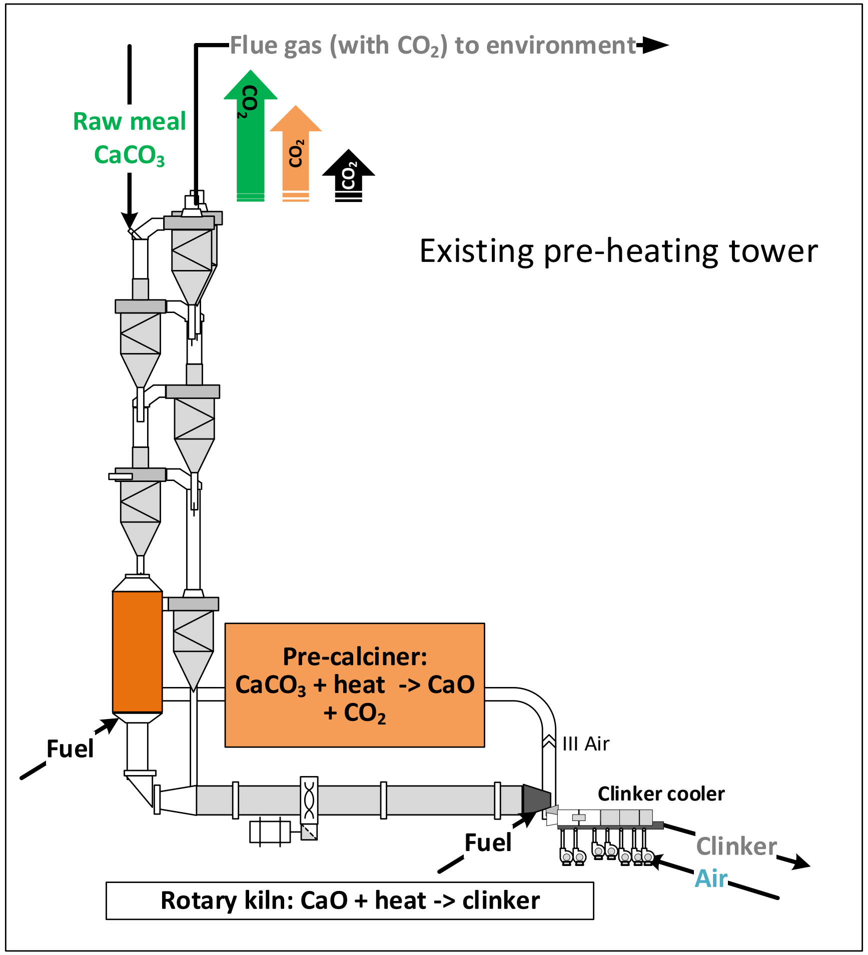
Chinese governement founding: 265.650 €

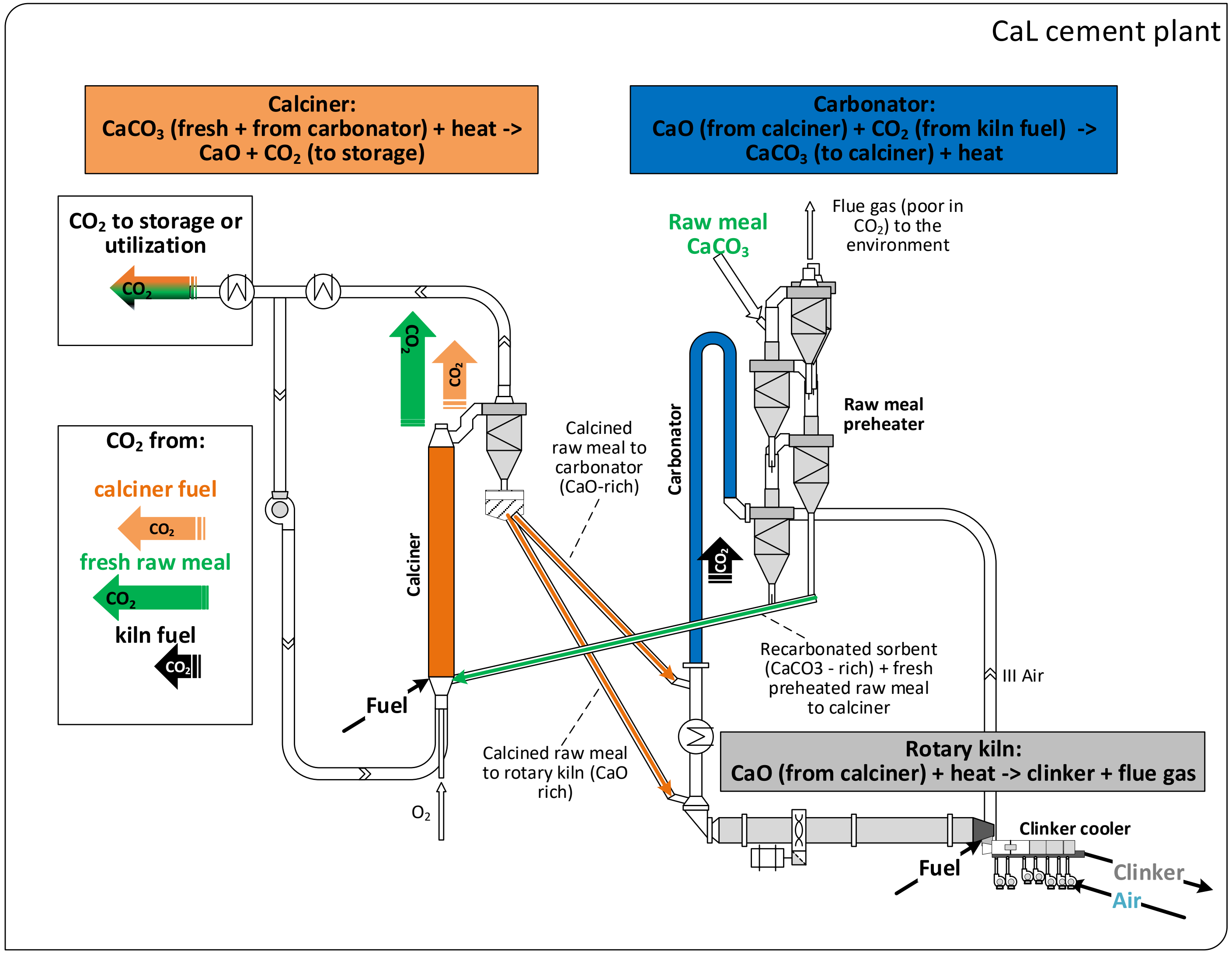
Partner: 13 from 5 EU member states + Switzerland and China



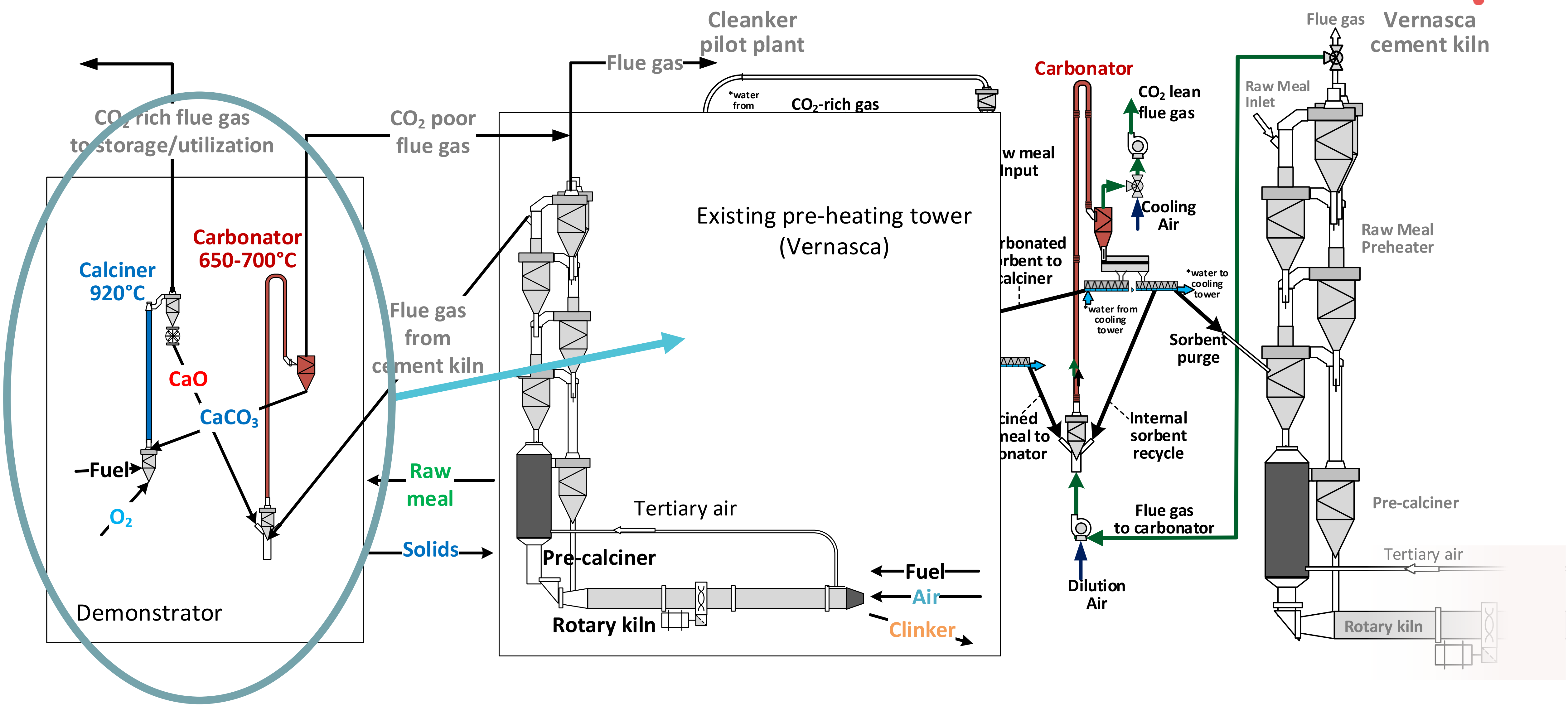


Calcium looping in cement industry – integrated configuration

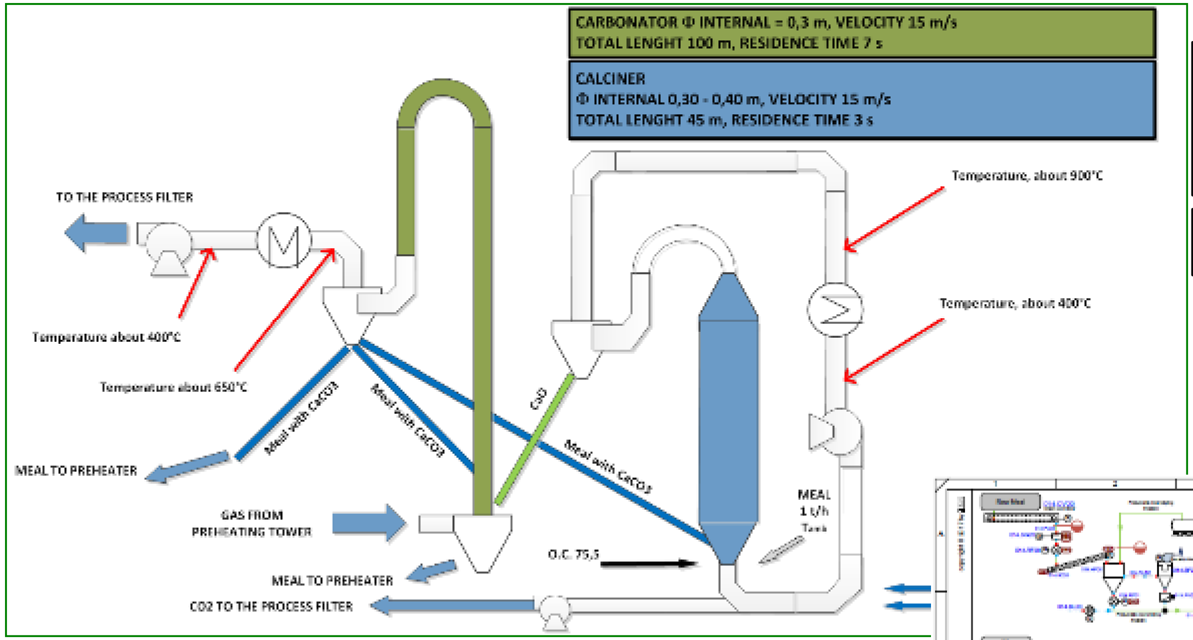




Indicative configuration of the CLEANKER pilot

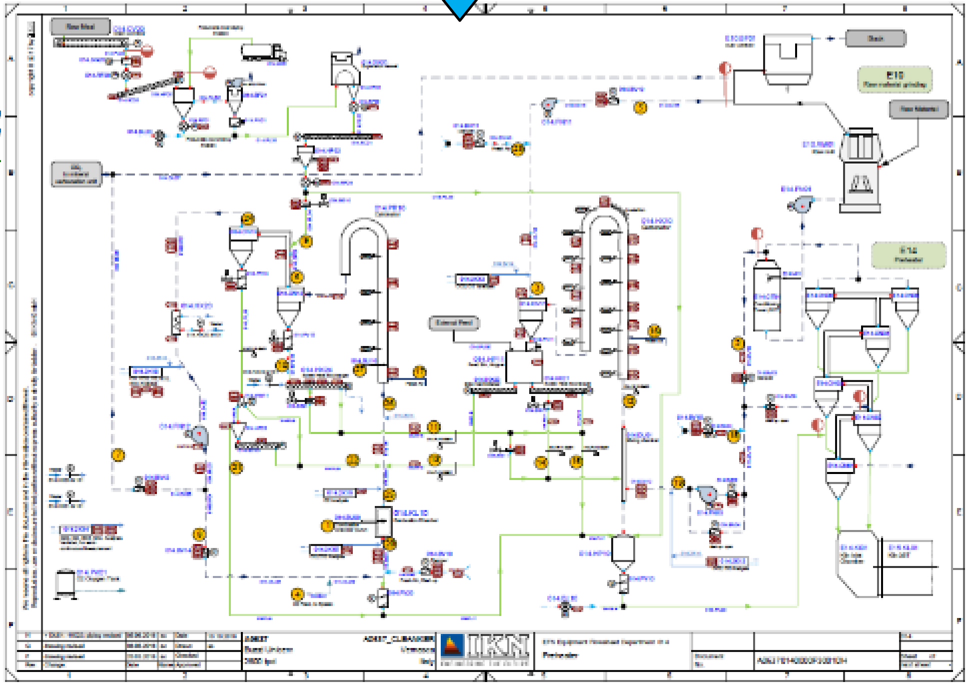


Flowsheet of the CLEANKER pilot



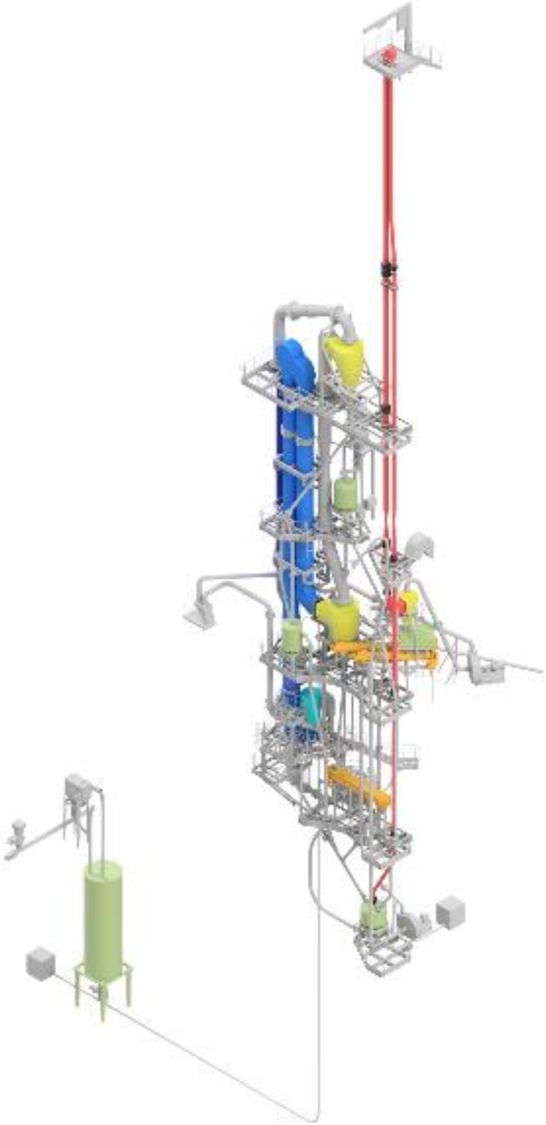
BASIC FLOWSHEET FOR THE APPLICATION

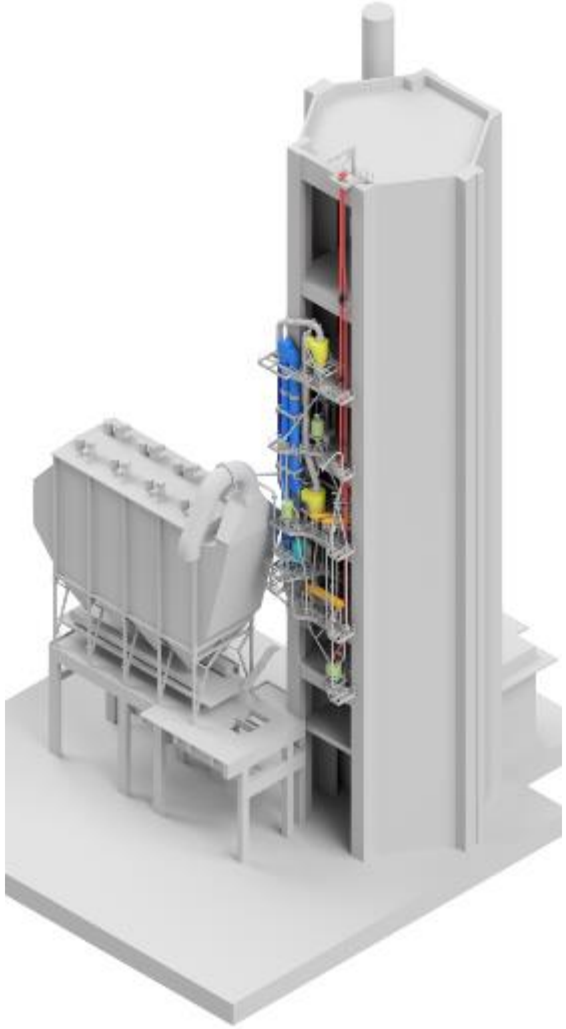
FINAL FLOWSHEET OF THE TEST RIG



CLEANKER demo system

Preheater tower





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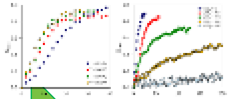
CLEANKER – timeline

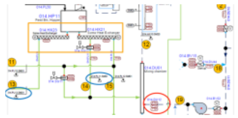
1st October 2017

17-18 October 2017
Kick-off meeting
(Piacenza)

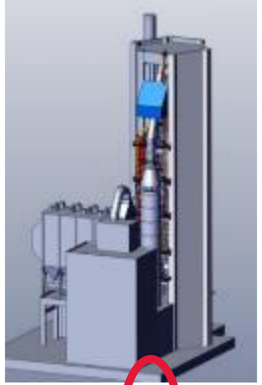
July 2018
Raw meal
characterization



June 2018
Measuring
points and
instrumentation



July 2018
Final Plant
layout

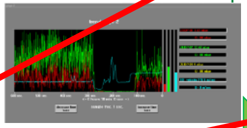


March 2019
Main items
fabrication

2017 2018 2019 2020 2021

March 2020
Erection

November
2020
Running tests



September
2020
Inspection

April 2021
Casting concrete
results
and full economic
analysis of cement
plant with CaL

September
2021
Final
conclusions

30th September 2021

Coming Soon

The demo plant in place

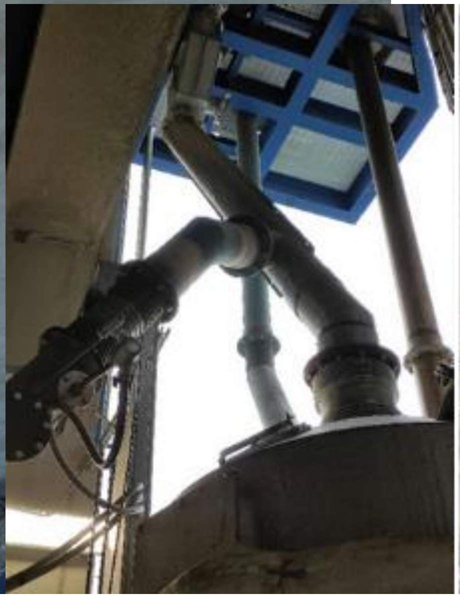
Co-funded by the Horizon 2020
Framework Programme of the European Union

Opening event

Co-funded by the Horizon 2020
Framework Programme of the European Union

Carbonator

- EFR, stainless steel, gooseneck shape;
- upcomer and downcomer, for a total length of approx. 105 m;
- section diameter: 250 – 350 mm;
- «swirl head».



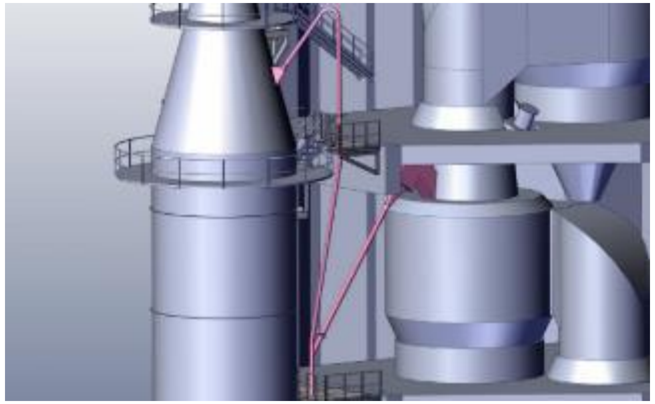
Calciner

- **Two burners;**
- **Heavy-oil fuel;**
- **Oxygen flow rate controlled to keep its concentration in the oultet gas stream at 4%;**
- **cyclone separates the calcined solids from the CO2-rich gas stream.**

CLEANKER – Communication and dissemination strategy

www.cleanker.eu

https://www.youtube.com/watch?v=7X8YJeR65cM&t=33s



26° August 2020, RAI1, SUperQuark, Piero Angela - https://www.youtube.com/watch?v=oQcrWfRbFJg

https://www.youtube.com/watch?v=RIXDjWLJPrA

CLEANKER community in Zenodo: https://zenodo.org/communities/cleanker?page=1&size=20

Acknowledgments

For any question:

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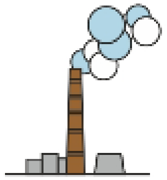
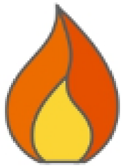
Project targets

Objective	Key indexes	Target
CO_2 **emissions** 	• CO_2 capture efficiency • CO_2 specific emissions	• Cement plant CO_2 capture efficiency >90% • Negative direct CO_2 emissions by biomass co-firing (Bio-CCS) • Reduction of total CO_2 specific emissions (kg_{CO2} per ton of cement) >85%
Energy efficiency 	• Fuel consumption • Electricity consumption • Specific primary energy consumption for CO_2 avoided (SPECCA*)	• increase of total fuel consumption with respect to state of the art plants <40% • increase of electric consumption with respect to state of the art plants <20% • SPECCA* < 2 MJ_{LHV} per kg of CO_2 avoided • SPECCA* at least 10% lower than that of benchmark full oxyfuel cement plants
Economics 	• Cost of cement • Cost of CO_2 avoided	• Increase of cement cost < 25 €/$_{tcement}$ • Cost of CO_2 avoided <30 €/t_{CO2}

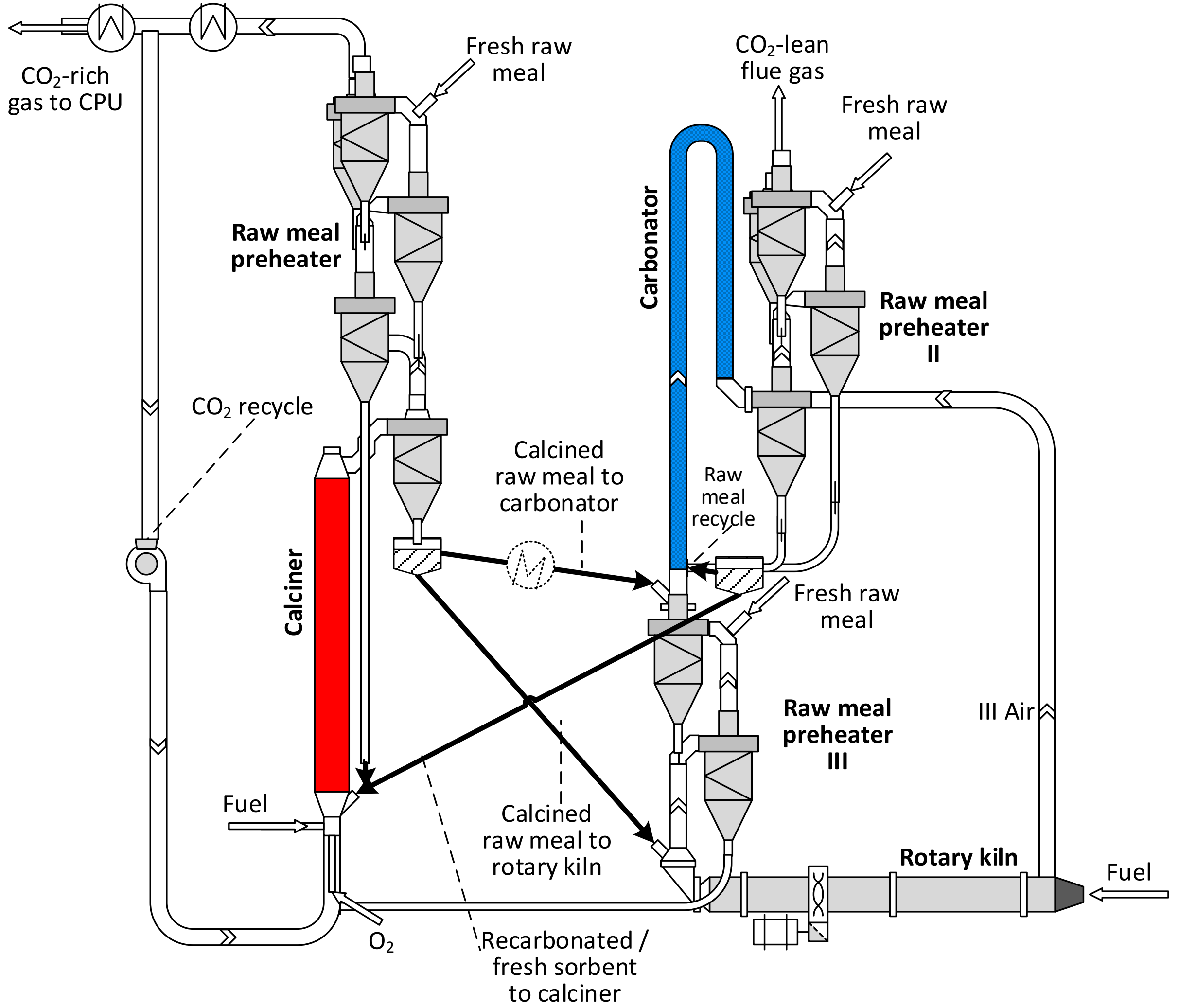
**SPECCA = Specific primary energy consumption for CO_2 avoided*

Co-funded by the Horizon 2020 Framework Programme of the European Union

Main technologies for CO_2 capture in cement plants

Calcium Looping

- **Integrated CaL:**
  - CaL carbonator highly integrated within the preheater, captures CO_2 from rotary kiln gas
  - CaL calciner coincides with the cement kiln pre-calciner -> no double calcination, lower fuel consumption
  - Calcined raw meal as CO_2 sorbent in the carbonator instead of high purity limestone
  - Sorbent has small particle size (d_{50}=10-20 µm) -> entrained flow reactors



Alonso et al., 2018. Energy & Fuels, 31, 13955–13962.
Turrado et al., 2018. Ind Eng Chem Res, 57, 13372-13380.
De Lena et al., 2019. Int J Greenh Gas Control, 82, 244-260.

Experimental campaigns

Nine experimental campaigns have been scheduled, five short tests of three days each one and 4 long tests of one week each one.

The aim of the short tests is to identify the most attractive operating conditions for the longer test runs. Therefore, particular attention will be given to the analysis of the governing parameters of the CaL process, namely:

- **Oxydant for the calcination process: Air/Oxygen;**
- **Calciner outlet temperature;**
- **Type of CO2 sorbent;**
- **Gas flow rate at carbonator inlet;**
- **Solid to gas ratio in the carbonator;**
- **Solids temperature at carbonator inlet.**

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