9th High Temperature Solid Looping Cycles Network - Day 2: CLEANKER

9:10-9:25	**Cleanker project overview** - Maurizio Spinelli[a], Martina Fantini[b], Stefano Consonni[c] - *[a] LEAP, [b] Eucore [c] PoliMI*
9:25-10:10	**Sorbent properties and lab scale tests for cement applications** J. Carlos Abanades[a], Borja Arias[a], Monica Alonso[a], Jose Ramon Fernandez[a], Sandra Turrado[a], Nico Mader[b], Joerg Maier[b] - *[a] CSIC-INCAR, [b] University of Stuttgart* -
10:10-10:25	**Cleanker pilot plant design** - Jörg Hammerich, *IKN GmbH* -
10:25-10:55	**Cleanker pilot test results** - Francesco Magli[a], Edoardo De Lena[b], Riccardo Cremona[c], Maurizio Spinelli[b], Monica Alonso[d], Nico Mader[e], Marco Lindeman Lino[f], Manuele Gatti[c], Matteo C. Romano[c] *[a]Buzzi Unicem SpA, [b]LEAP, [c]Politecnico di Milano, [d]CSIC-INCAR, [e] University of Stuttgart, [f] VDZ Technology gGmbH,*
Coffee break	
11:15-11:35	**Simulation and validation of reactor models of Cleanker Vernasca pilot** Kari Myöhänen, Jouni Ritvanen - *LUT University*
11:35-12:05	**Cleanker process analysis and retrofitting** Edoardo De Lena[a], Maurizio Spinelli[a], Riccardo Cremona[b], Matteo C. Romano[b], Guido Pellegrino[c], Ancelin Coulon[d], Anna Kounina[d] - *[a] LEAP, [b] Politecnico di Milano, [c] Italcementi-HeidelbergCement, [d] Quantis*
12:05-12:25	**Scale-up and economics for a full-size plant** Jörg Hammerich[a], Marco Lindeman Lino[b], Kari Myöhänen[c] - *[a] IKN GmbH, [b] VDZ Technology gGmbH, [c] LUT University*
12:25-12:50	**CO_2 utilization, transport and storage study** Alla Shogenova[a], Kazbulat Shogenov[a], Mai Uibu[a], Rein Kuusik[a], Mustafa Cem Usta[a], Daniela Gastaldi[b], Fulvio Canonico[b], Guido Pellegrino[c] - *[a] Tallinn University of Technology, [b] Buzzi Unicem, [c] Italcementi-HeidelbergCement*
12:50-13:10	**Cleanker strategic conclusions** - Matteo Romano[a] , Maurizio Spinelli[b] - *[a] Politecnico di Milano, [b] LEAP*
Lunch (13:30-14:15)	
14:15 – 19:00 Cleanker pilot plant visit	

14:15 – 19:00 Cleanker pilot plant visit

- **14:15**: Departure from Piacenza
- **15:15**: Arrival at Vernasca cement plant
- **15:15-15:45**: Introduction and preparation to the visit
- **15:45-16:30**: Visit to the pilot plant and to the cement plant
- **16:30-17:00**: End of the technical visit and coffee break
- **17:00-17:45**: Presentation and final discussion (meeting room)
- **18:00**: Departure from Vernasca (back to Piacenza)

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

CLEAN clinKER by calcium looping for low-CO_2 cement

CLEANKER Project Overview

M. Spinelli[a], M. Fantini[b], S. Consonni[c]

[a]LEAP (Laboratorio Energia e Ambiente Piacenza), [b]Eucore, [c]Politecnico di Milano,

9th High Temperature Solid Looping Cycles Network (HTSLCN) Meeting
Piacenza, Palazzo Farnese
Day 2 - 15/03/2023

LEAP
FOUNDED IN 2005 BY POLITECNICO DI MILANO

CLEANKER – Primary objectives

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

- install and operate a new demo system at TRL 7 based on the integrated CaL process, connected to 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 CO_2 mineralization of the captured CO_2 (inorganic materials, small-scale pilot reactor)

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

Starting date: October 1st 2017

Duration: 4 years + extension due to Covid

Total budget: € 9.237.851,25

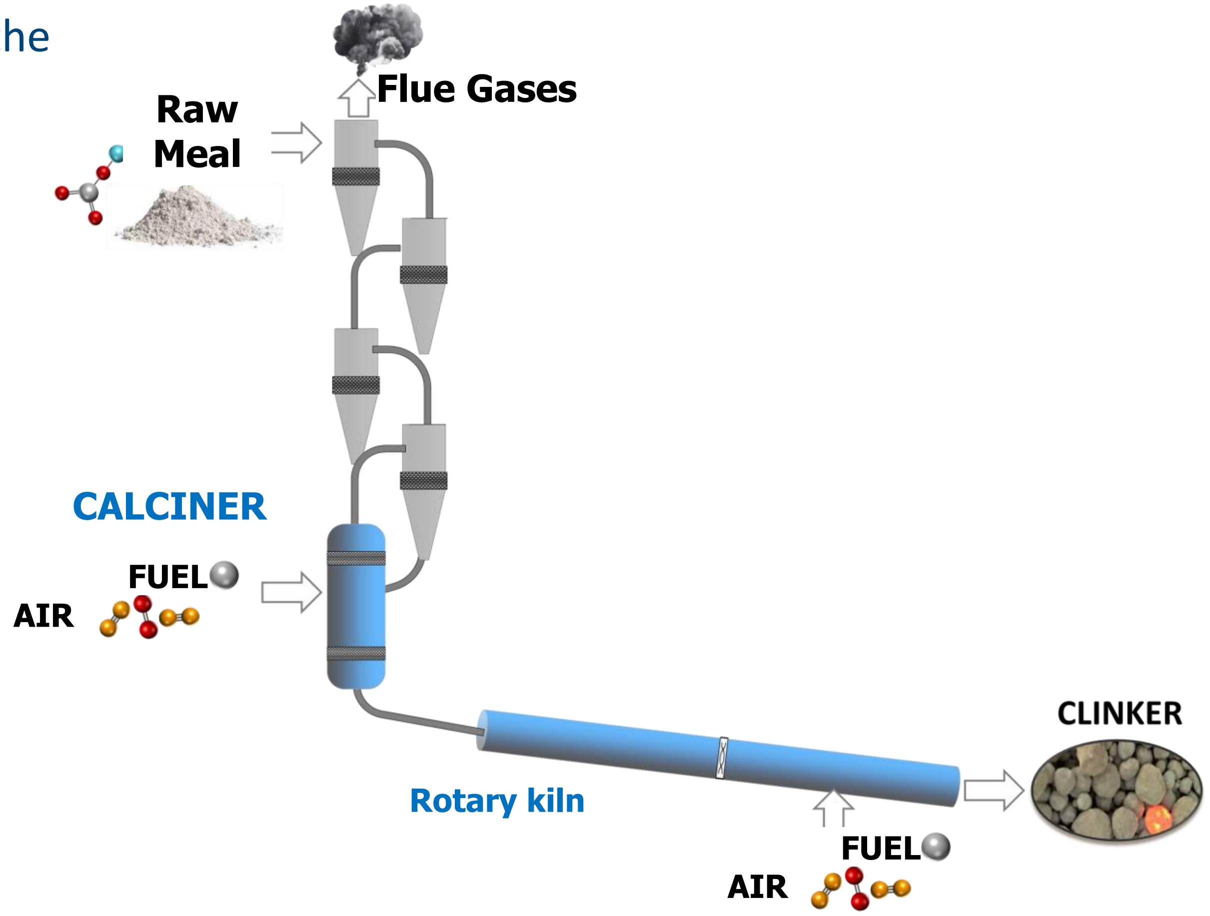
UE co-financing: € 8.972.201,25

Chinese governement founding: 265.650 €

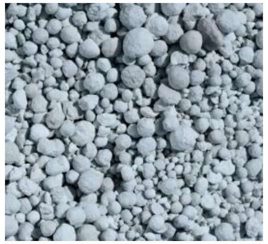
Co-funded by the Horizon 2020 Framework Programme of the European Union

CO_2 emissions in cement making

- The production of **1 ton of cement** implies the emission of **670 kg of CO_2**



1 ton cement



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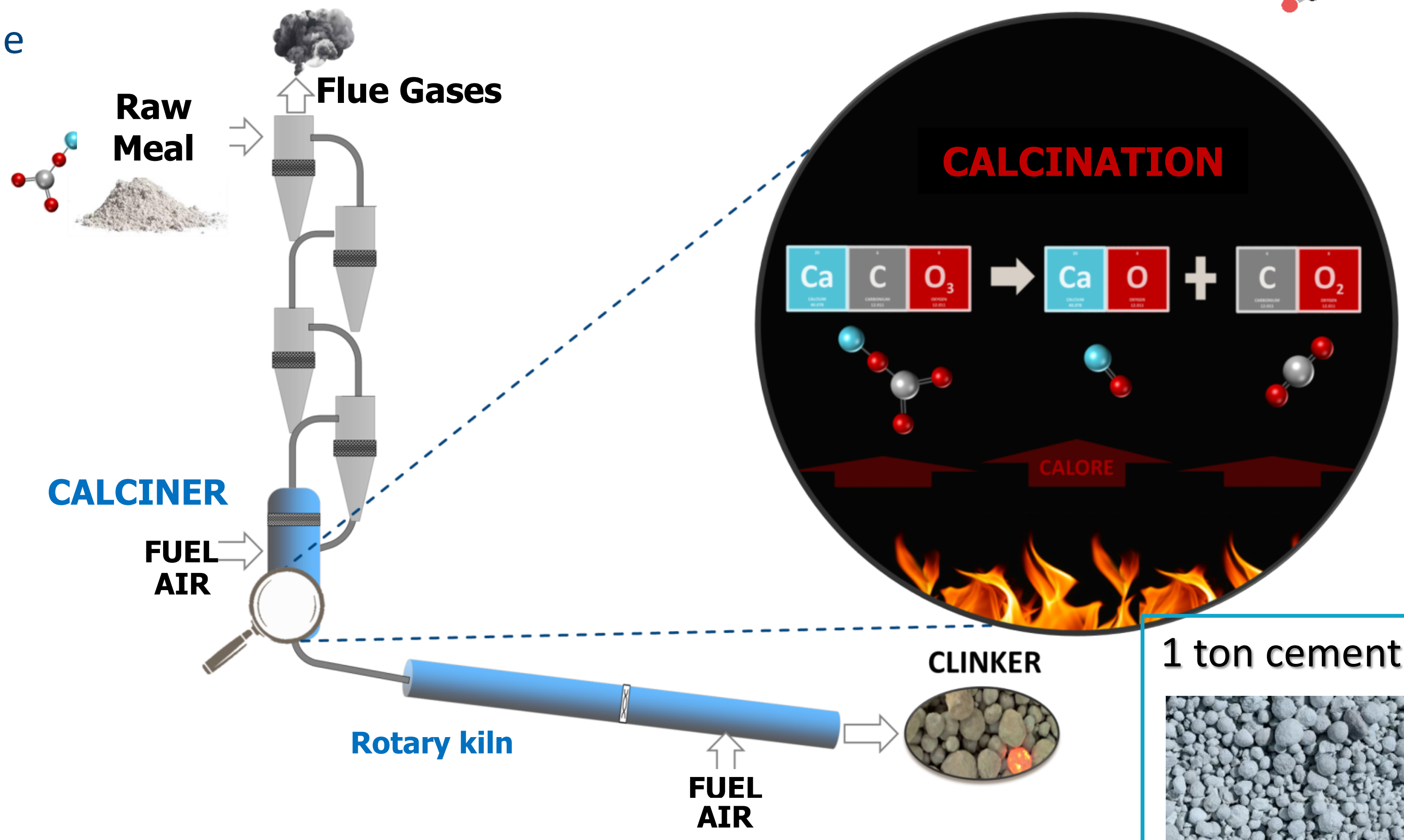
670 kg CO_2

CO_2 emissions in cement making

- The production of **1 ton of cement** implies the emission of **670 kg of CO_2**
- Most of **CO_2 in generated by the calcination process;** in the ***calciner***, calcium carbonate ($CaCO_3$) of the raw meal is decomposed into calcium oxide (CaO) & carbon dioxide (CO_2)



1 ton cement
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670 kg CO_2

CO_2 emissions in cement making

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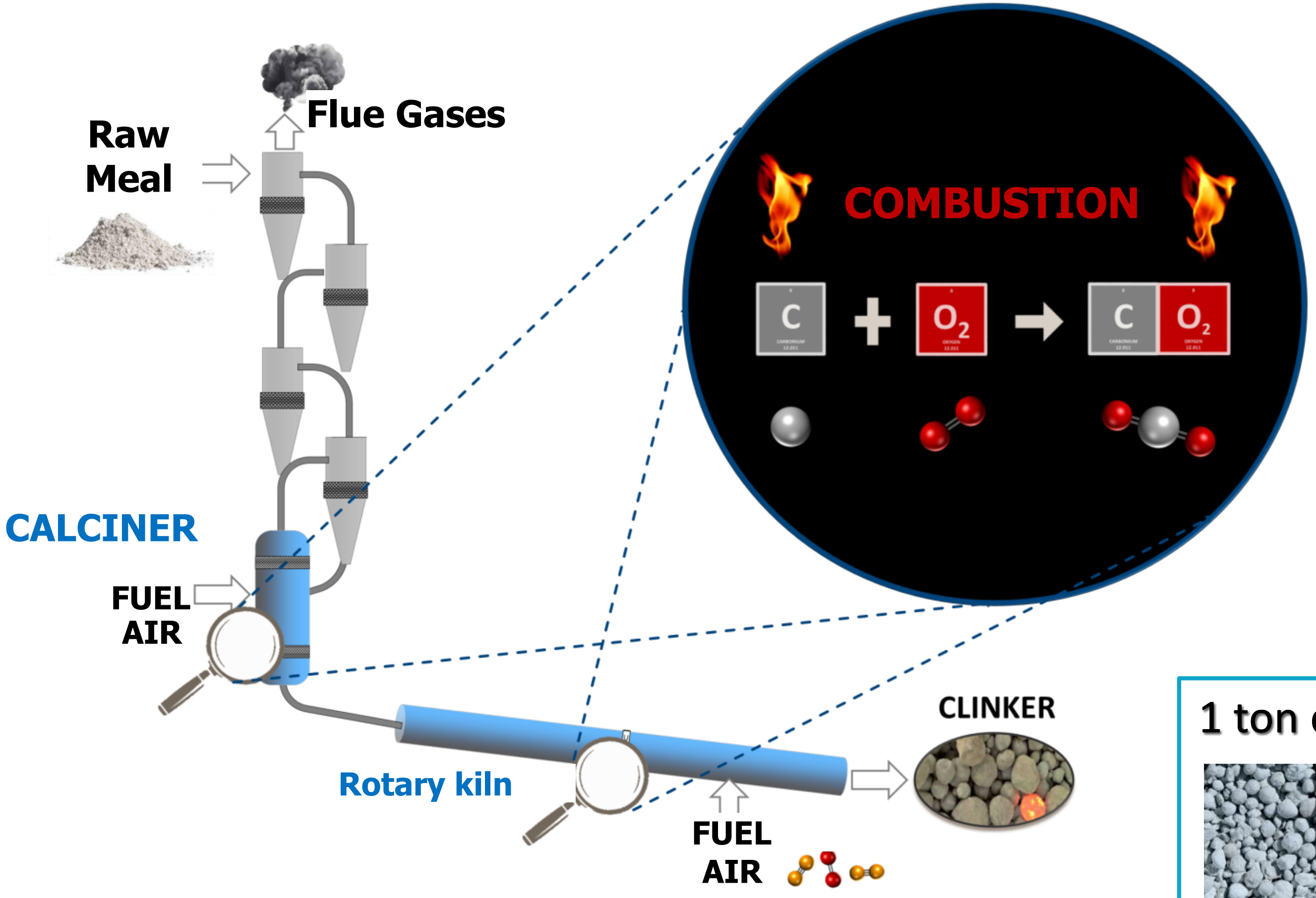
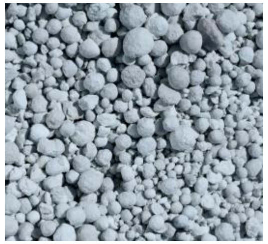
- Most of **CO_2 in generated by the calcination process;** in the ***calciner***, calcium carbonate ($CaCO_3$) of the raw meal is decomposed into calcium oxide (CaO) & carbon dioxide (CO_2)
- Calcination is an endothermic reaction, requiring heat → **first combustion → additional CO_2 emissions**
- The final product (CLINKER) is produced in the ***rotary kiln*** by heating the hot meal up to 1450°C → **second combustion → additional CO_2 emissions**



- **Eliminating all the combustion steps (e.g. by exploiting renewable energy) would not be sufficient to completely decarbonize cement making process!**

1 ton cement



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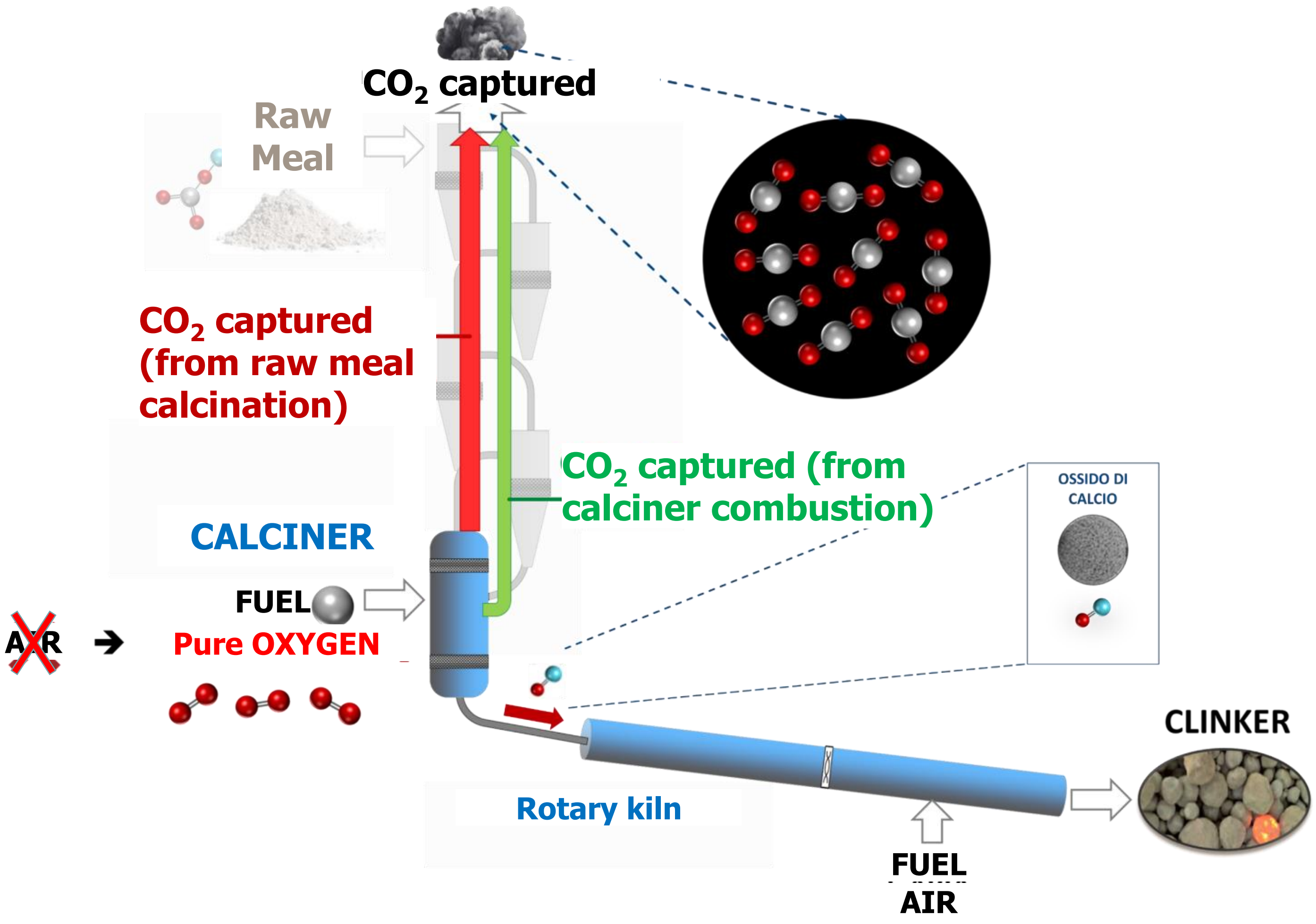
670 kg CO_2

Integrated Calcium-looping process

- The first step required for implementing the integrated CaL is to switch the ***calciner*** from air combustion to **pure oxyfuel combustion**

→ *In this way, $\boldsymbol{CO_2}$ is produced at high concentrations and is ready for the following purification, transport and storage steps*



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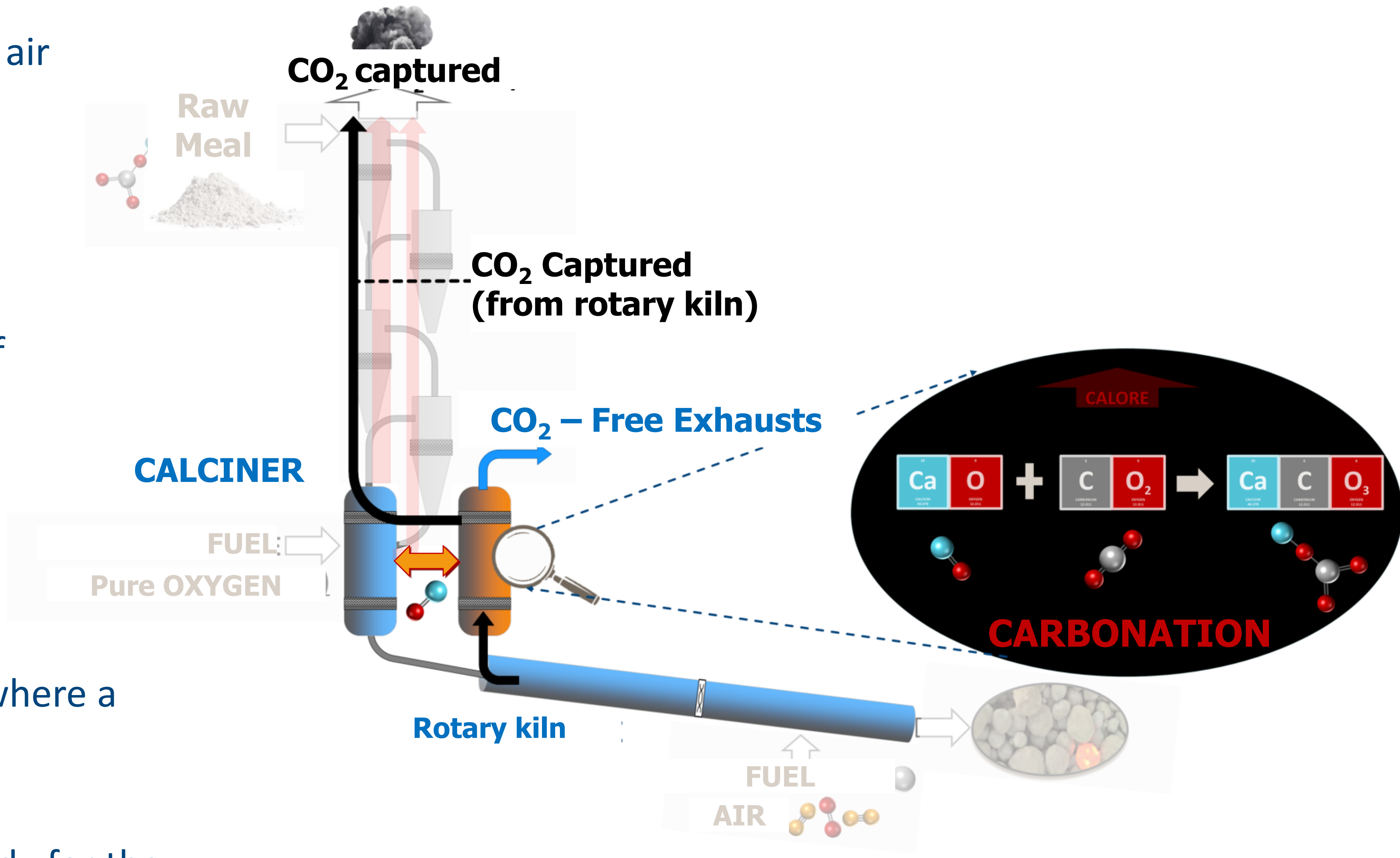
- The second step requires to use a fraction of calcium oxide (**CaO**) as CO_2 sorbent:

→ *In the **carbonator**, the CaO based material «captures» CO_2 from the effluents produced in the rotary kiln, forming $CaCO_3$*

- $CaCO_3$ is then recycled back to the calciner, where a second calcination generates:

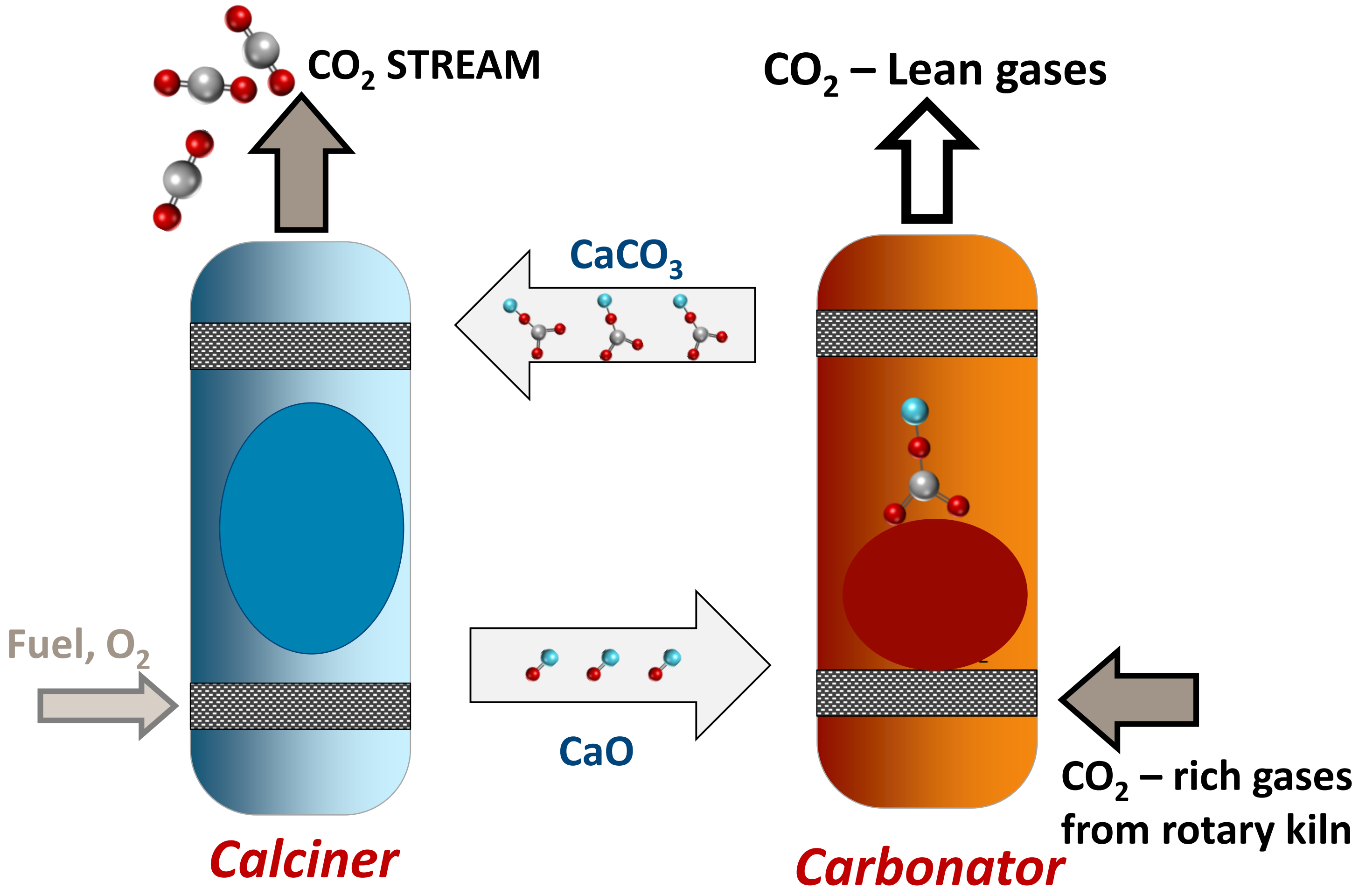
  1) a concentrated flow of **CO_2 captured**

  2) a flow of **regenerated sorbent** (CaO) ready for the next CO_2 capture cycle (Calcium – Looping)



Integrated Calcium-looping process

Calcium operates as a CO_2 carrier by concentrating CO_2 from the rotary kiln effluents to a CO_2-rich gaseous strem released from the oxyfuel calciner.



Integrated Calcium-looping process

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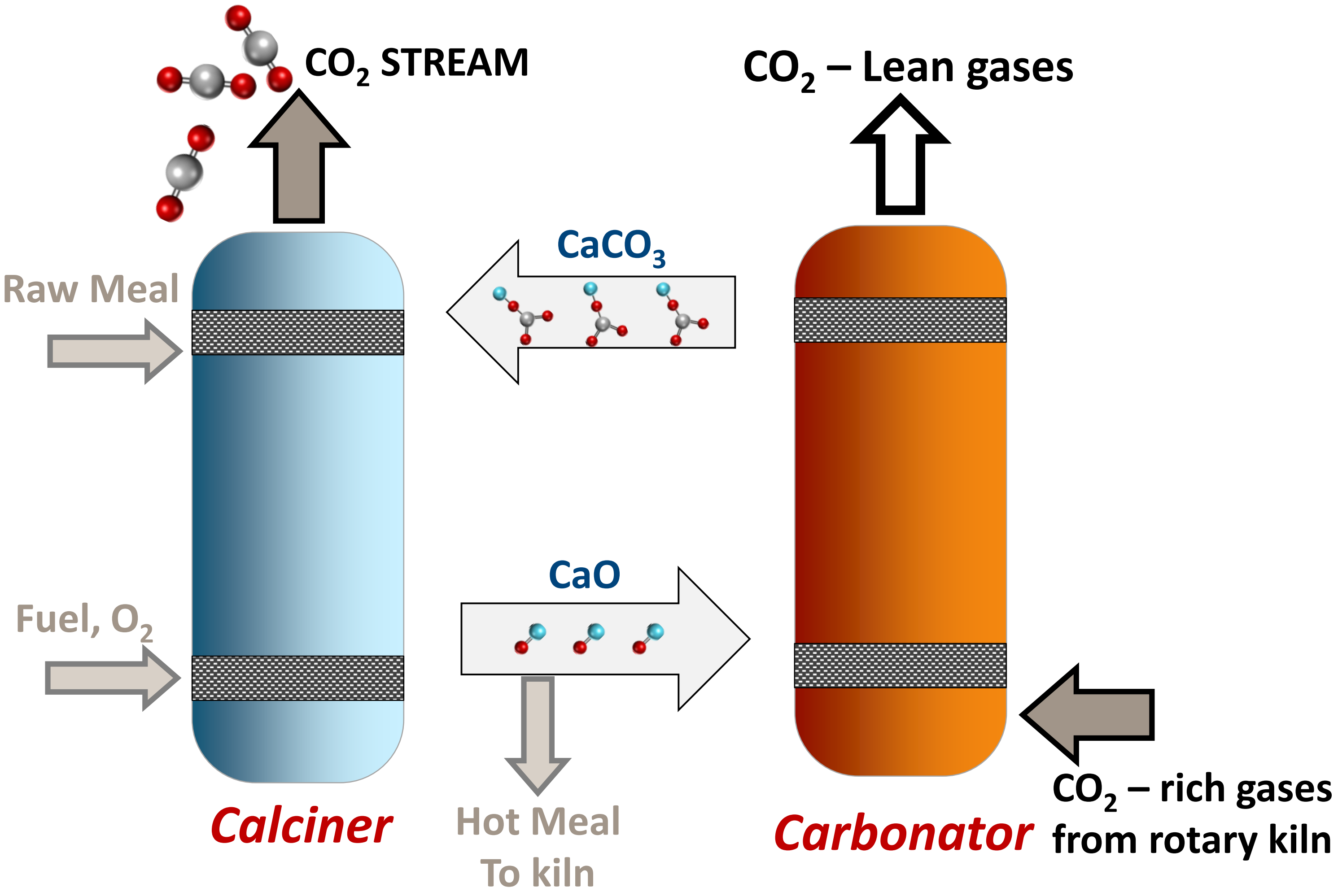
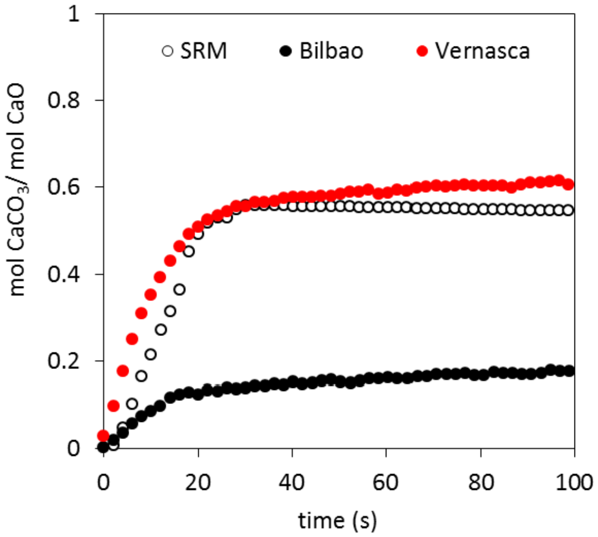
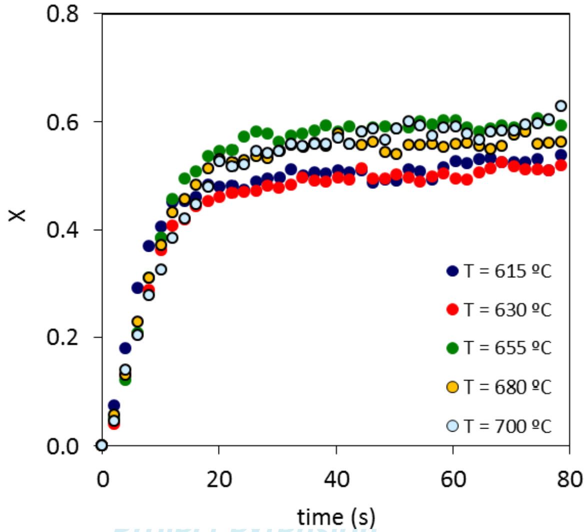
Integrated **CaL advantages**:
- No special equipment required
- Cement raw meal is the CO_2 sorbent
- No variation to rotary kiln and cooler

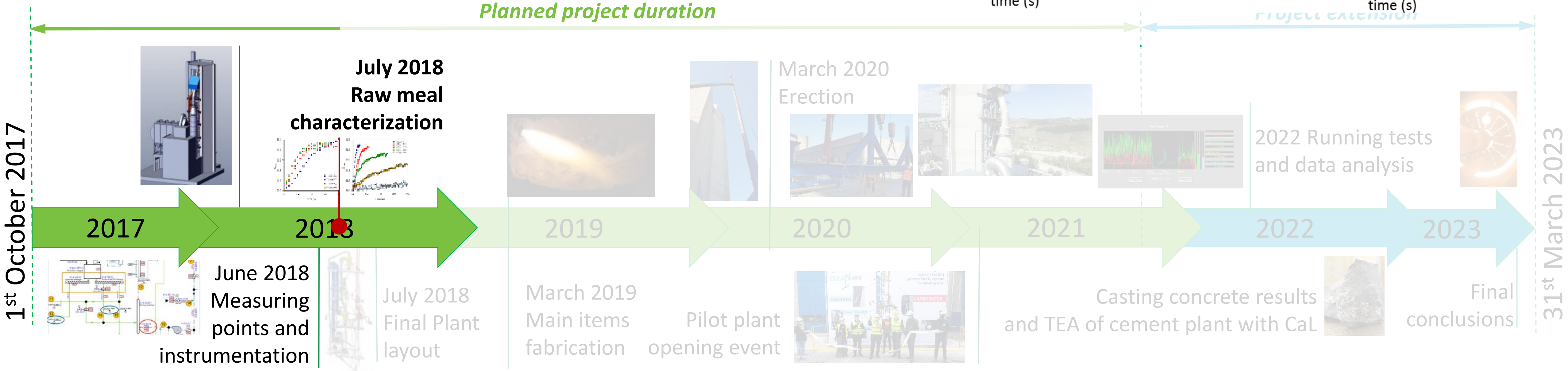


CLEANKER – Timeline: sorbent characterization

- **2017-2018:** evaluation of Vernasca raw meal properties and of its suitability to be exploited as CO_2 capture sorbent
- CSIC and USTUTT (Oviedo, Stuttgart) lab analysis shown that the material has sufficient carbonation kinetics and **CO_2 carrying capacity** for CaL applications







CLEANKER timeline: pilot construction

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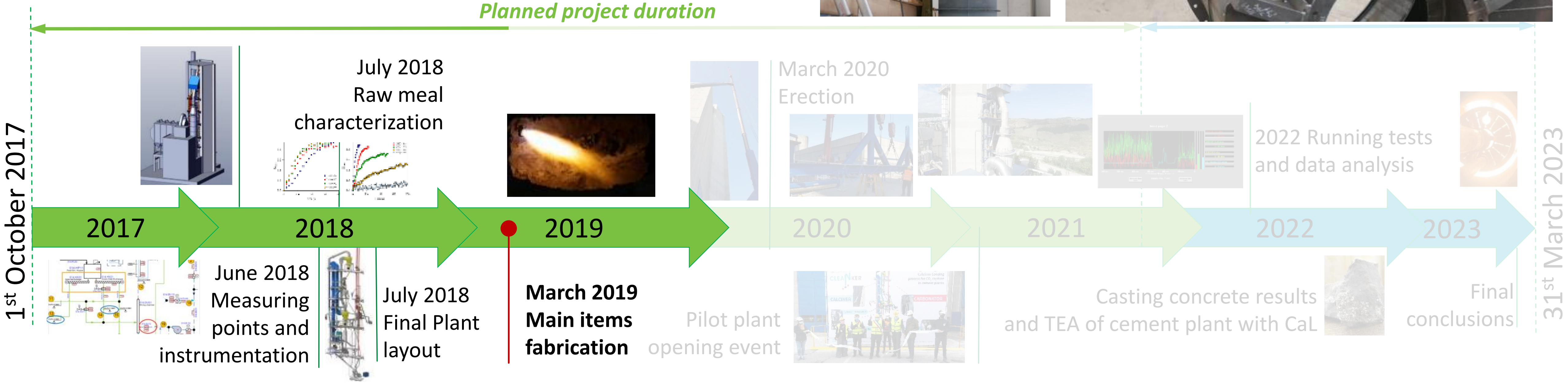
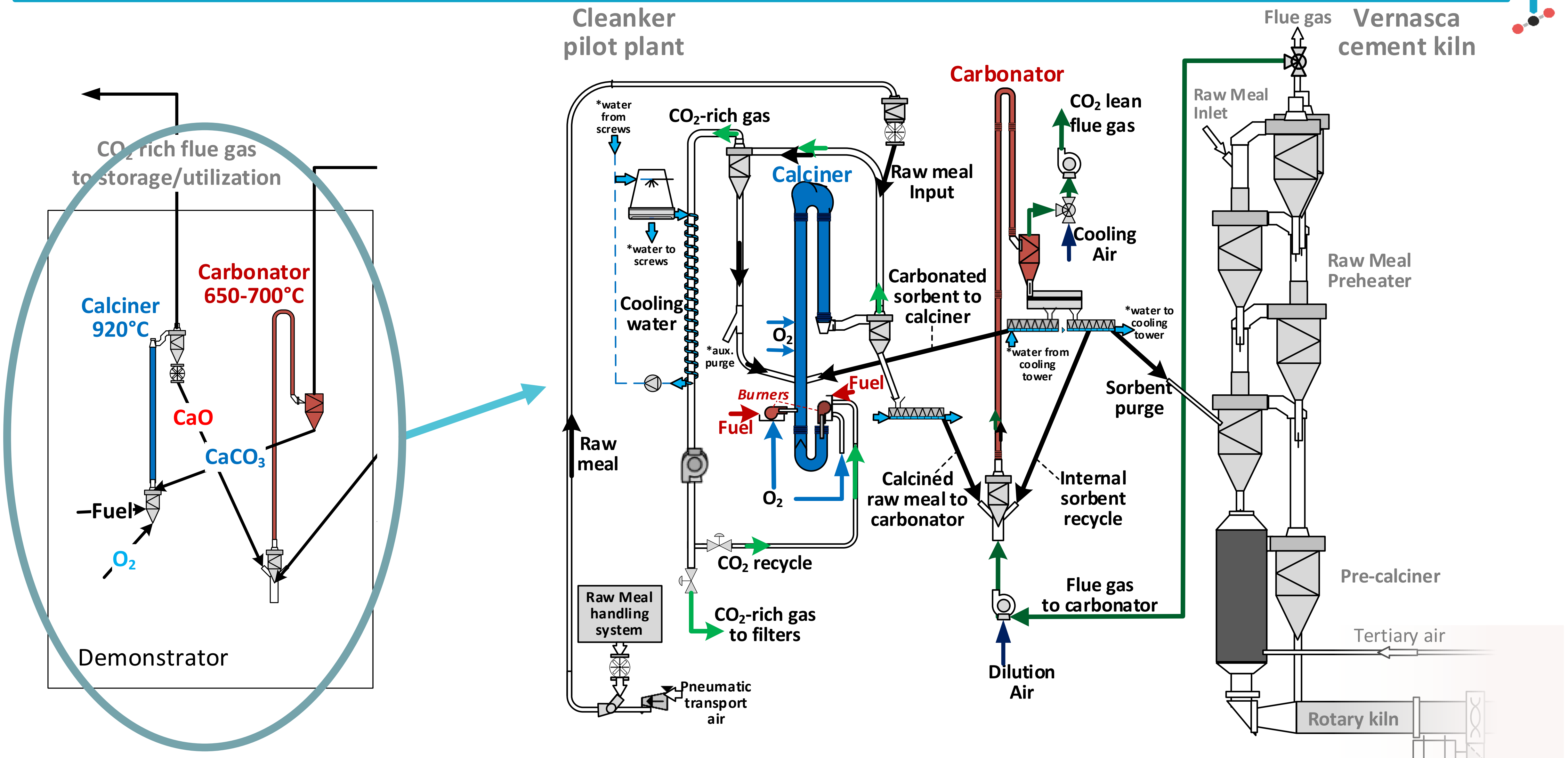
- **2017-2018:** pilot plant **design**
  - 693 technical sheets
  - 15 revisions to achieve an optimized process scheme
- **2019: construction** of pilot plant components

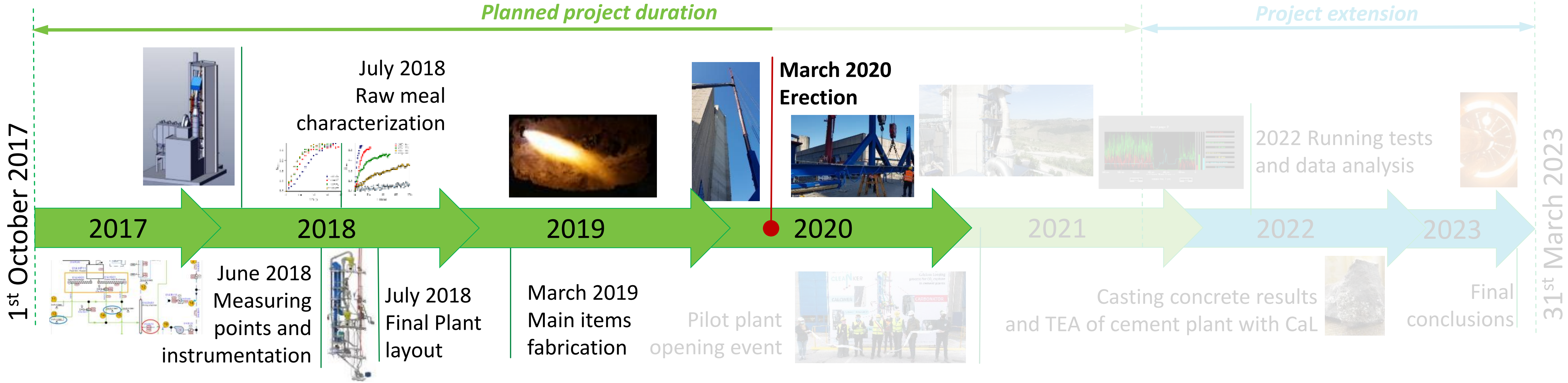


CLEANKER – Process scheme *(simplified)*



CLEANKER timeline: pilot erection

- **2020:** pilot plant **erection** in the Vernasca hosting site, owned by Buzzi Unicem
- **Installation of a total 110 tons of components and machineries** (+ 40 ton of refractory material), 38 big-size ducts, 78 expansion joints and 189 strumental devices



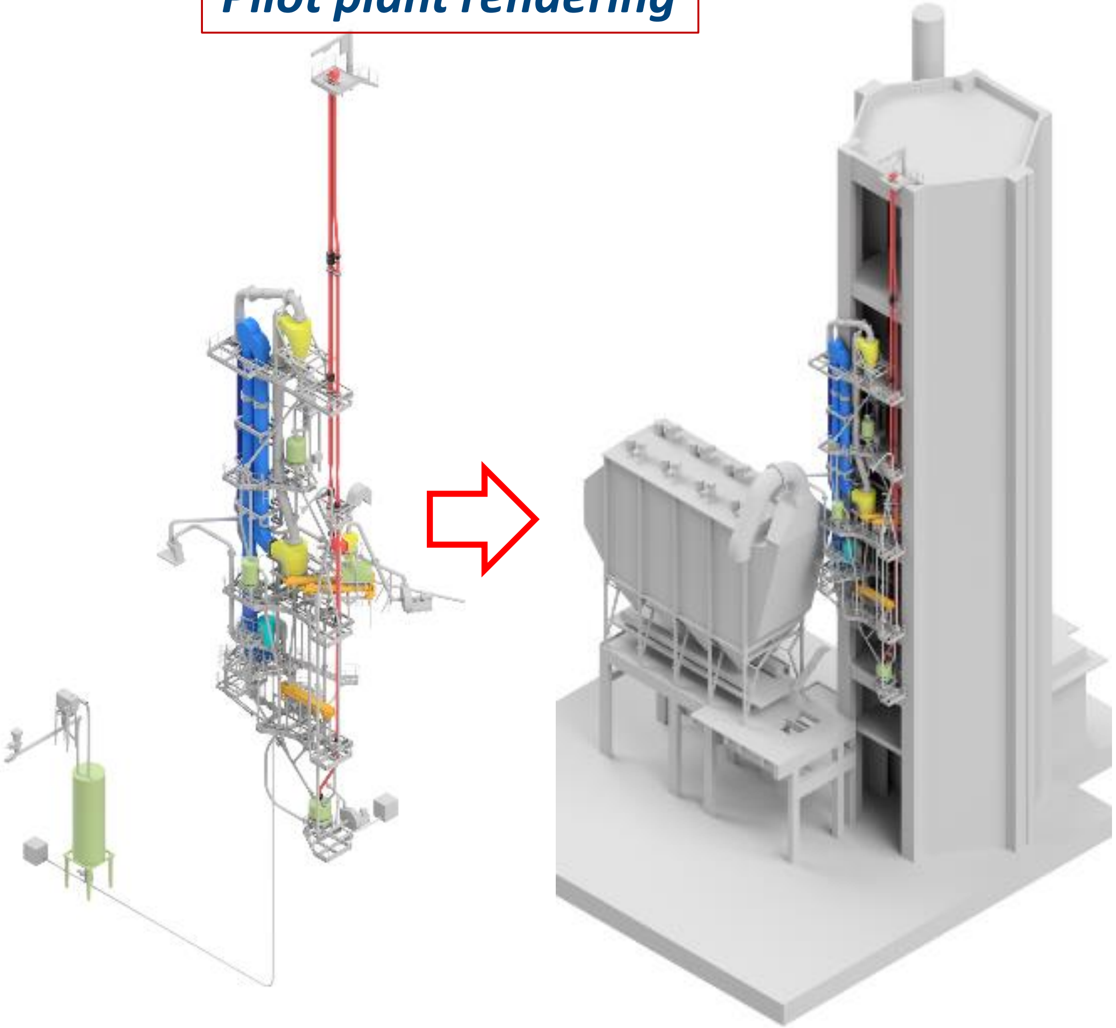
CLEANKER – Pilot plant

Vernasca cement plant

Buzzi Unicem

Cement plant preheating tower

Pilot plant rendering



CLEANKER calciner

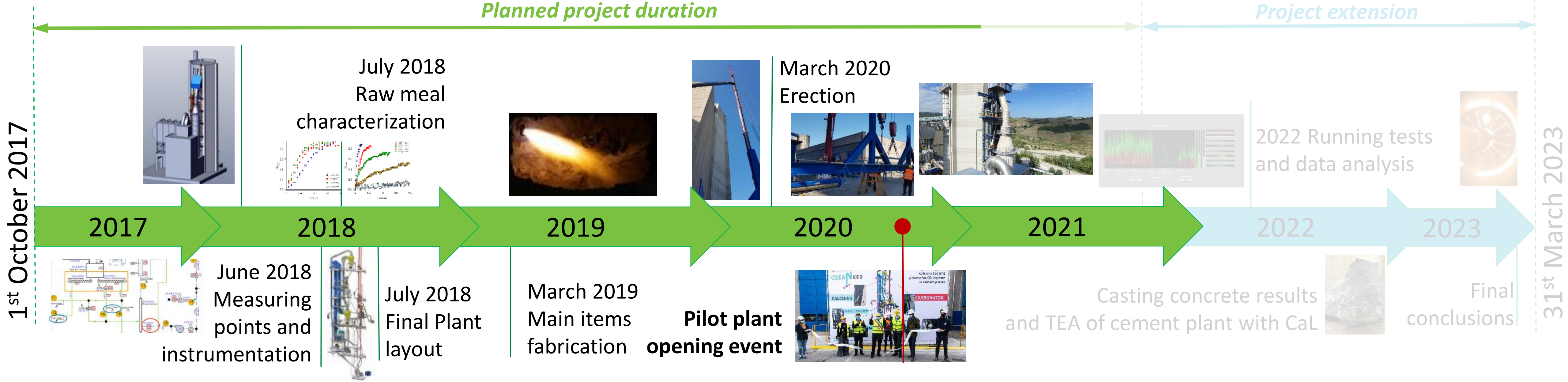
- **Two burners** (Heavy-oil fuel, oxycombustion)
- **Multiple Oxygen** injection points
- **CO_2 recycle** duct (cooled)
- **Rotary screw** to control solid circulation
- Raw material **preheating stage** (riser-cyclone)
- Gas/solid **cyclone** separators

CLEANKER carbonator

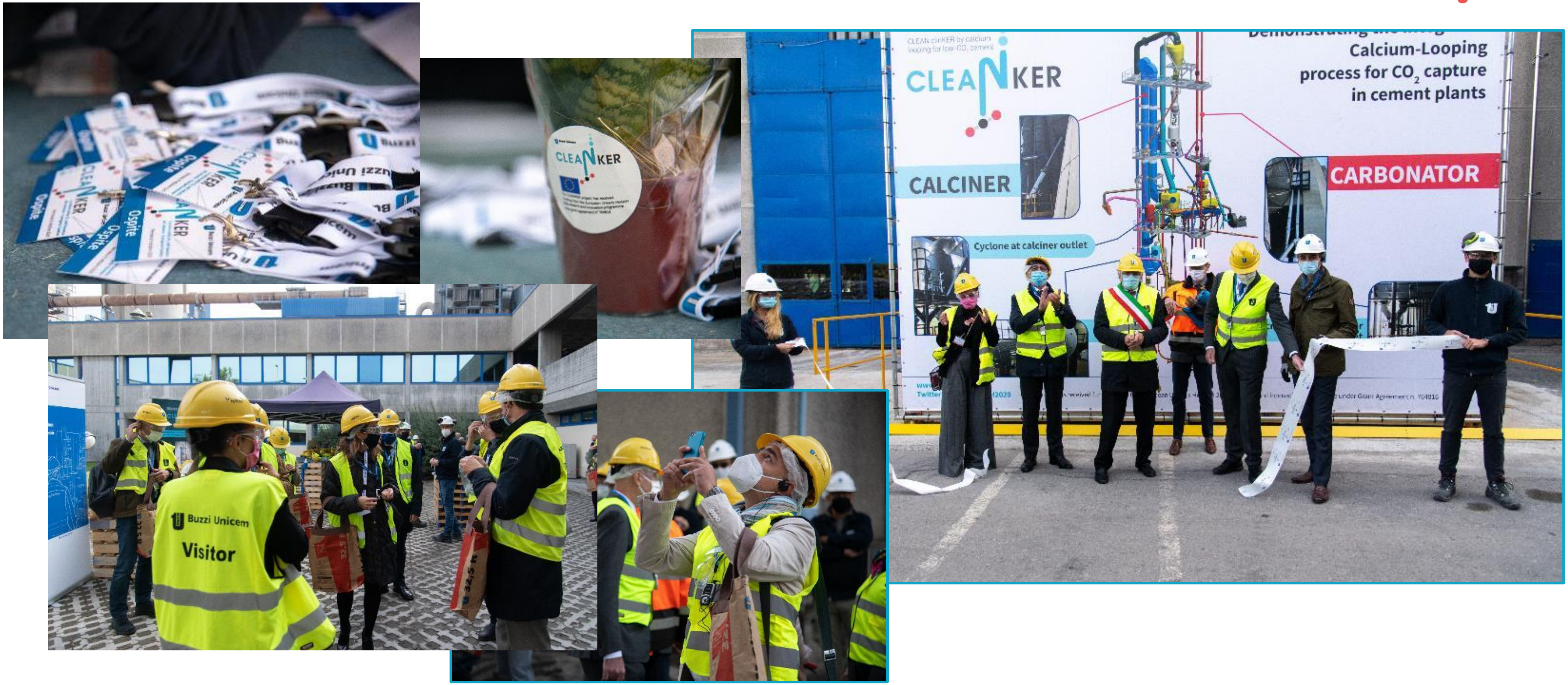
- **Overall length 105m,** variable diameter (250 mm upward– 350 mm downward)
- Stailness steel **eintrained flow reactor (EFR)**, gooseneck shape;
- **Cyclone** to separate carbonated meal from CO_2-free gases
- **Cooled screw** to sent the carbonated meal back to calciner

CLEANKER timeline – Opening event

- 9-10-2020 **Opening event** at Buzzi's premises in Vernasca: «*La cattura della CO_2 nell' industria del cemento – Il progetto CLEANKER*»
- 8 oral presentations + pilot plant visit
- CLEANKER stakeholders and policy makers have been involved
- Pilot plant **commissioning** was started right after the opening event



CLEANKER Opening Event



CLEANKER timeline – experimental campaigns

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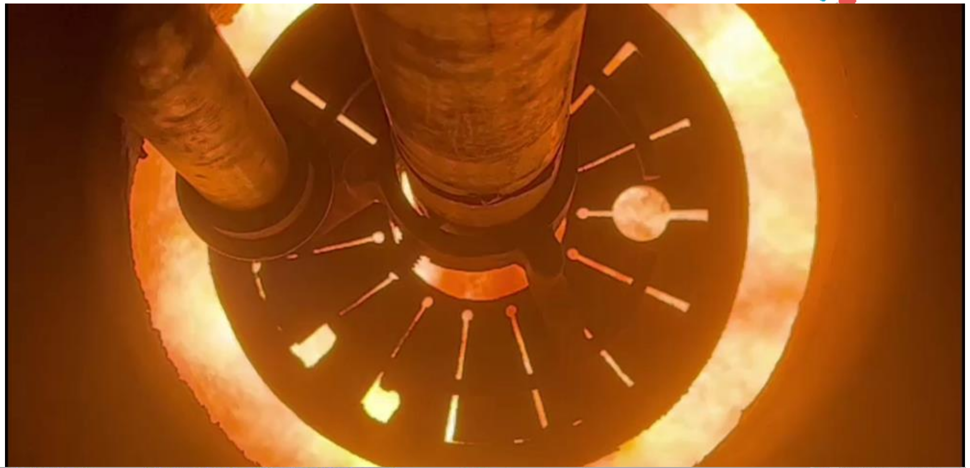
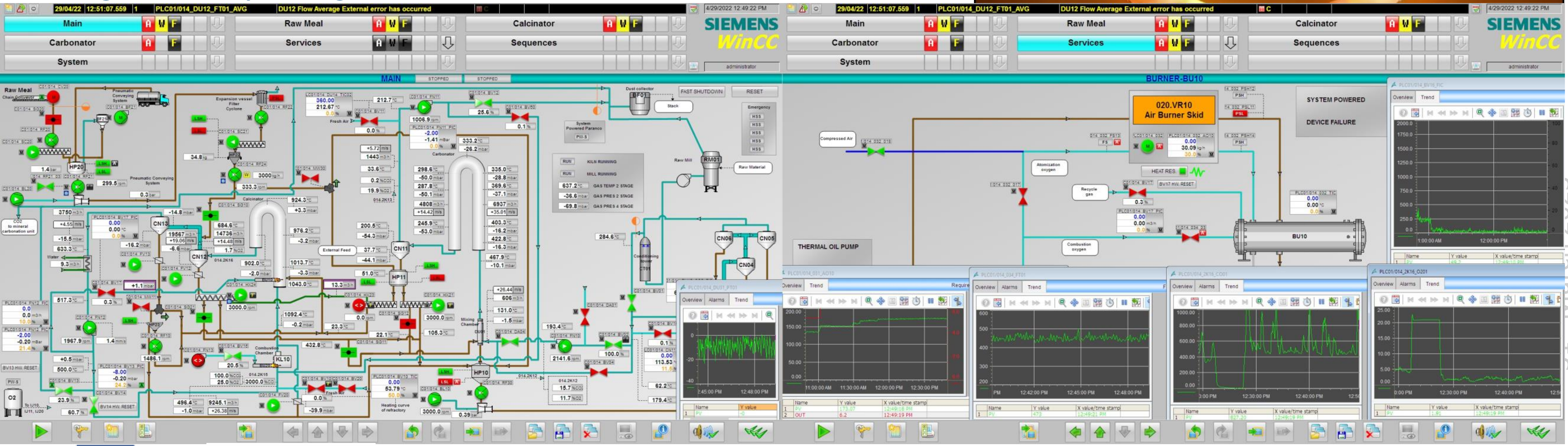
CLEAN clinKER by calcium looping for low-CO2 cement

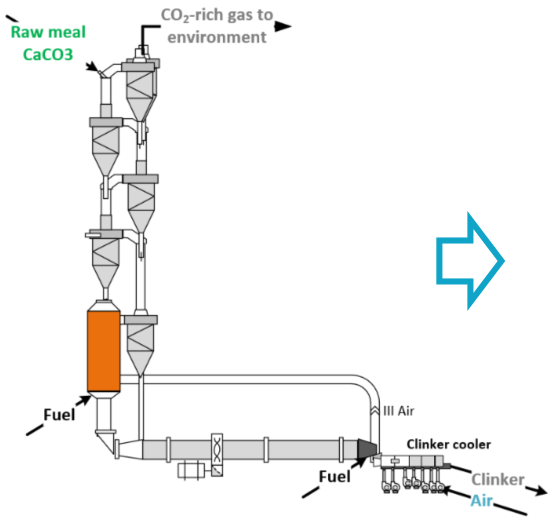
- **Experimental campaigns have been managed and executed by BUZZI operators, with the support of LEAP, PoliMI, VdZ and Stuttgart**
- **9** experimental campaigns: **5 short tests** of 3 days each and **4 long tests** of 1 week each) to evaluate the performances of the system as a function of main CaL parameters (e.g. solid/gas ratio, EFR reactors operating conditions)
- The pilot plant was operated for more than **100 hours in representative integrated Cal operating condition**

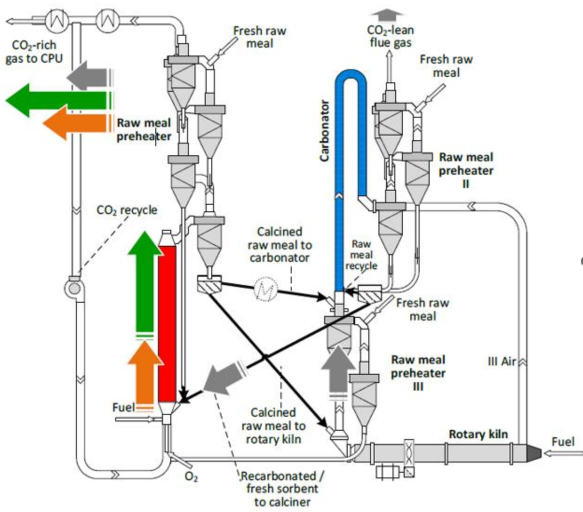




CLEANKER timeline – exploitation activities

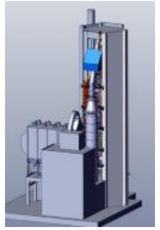
- CLEANKER consortium is evaluating all the technical aspects for the potential integration of CaL concept within different kind of cement plants
- **scale-up** studies for both retrofit & greenfield applications
- **business plan and TEAs** have been produced for the commercial exploitation of CLEANKER technology as a retrofit option for BUZZI and ITC (Heidelberg) cement plants



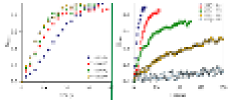


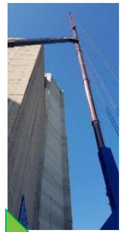
Planned project duration — *Project extension*

1st October 2017

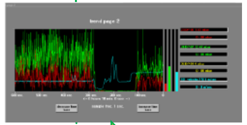


July 2018 Raw meal characterization



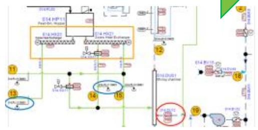


March 2020 Erection



2022 Running tests and data analysis

2017 — 2018 — 2019 — 2020 — 2021 — 2022 — 2023



June 2018 Measuring points and instrumentation

July 2018 Final Plant layout

March 2019 Main items fabrication

Pilot plant opening event

Casting concrete results and TEA of cement plant with CaL

Final conclusions

31st March 2023

CLEANKER in SUPERQUARK

CLEANKER

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

Cleanker experimental results

The raw meal used for making cement can be efficiently exploited **as CO_2 sorbent**, not only in controlled lab tests but also in **operational environment**

→ All the uncertainties related to sorbent properties and to the formation of **side species have been** overcome

Results

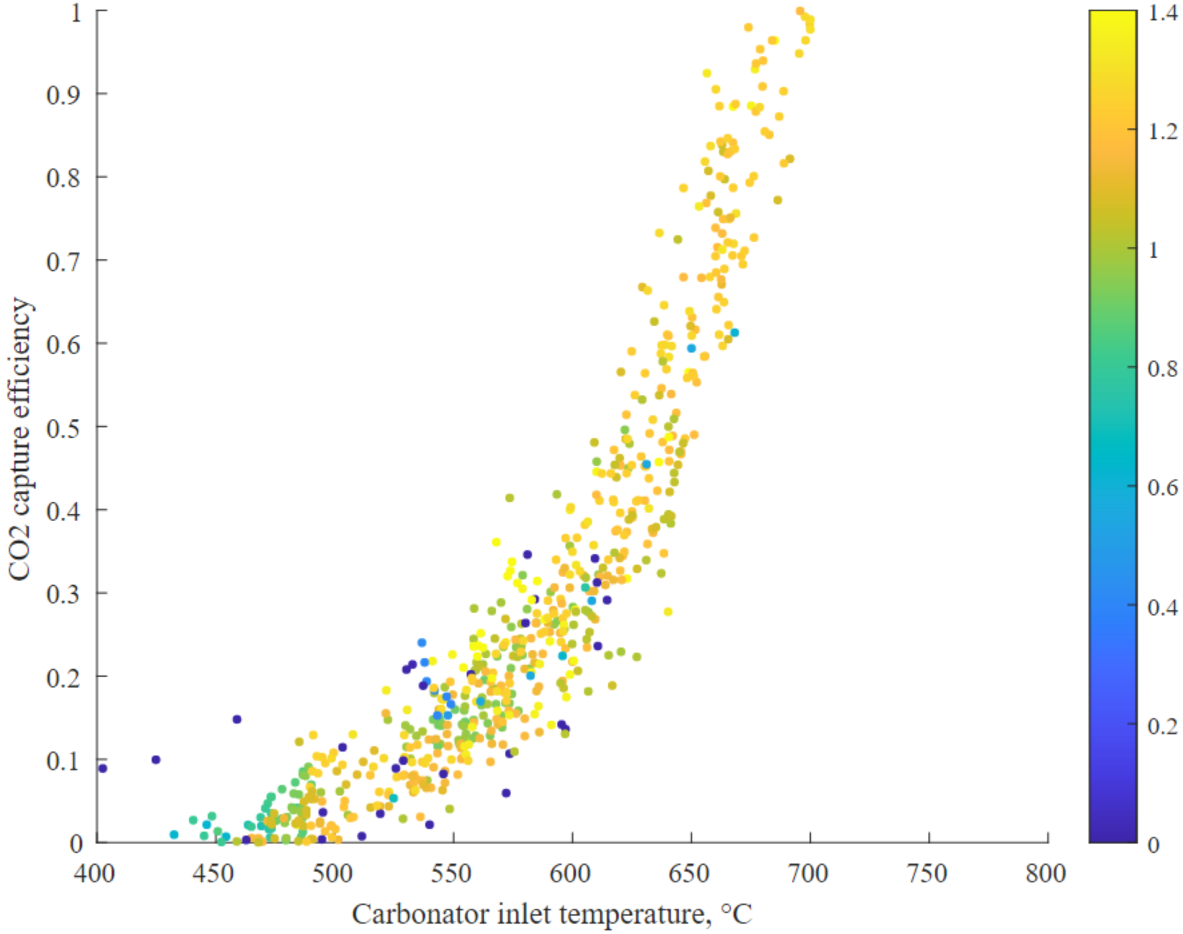
Carbonator:

- **Good CO_2 capture performances** in a wide range of inlet T (550-700°C), confirmed by gas and solid analyses
- Linear trend between the increase in the Ca to CO_2 ratio and the **CO_2 capture rate**

Calciner:

- Pilot operation continuously improved during tests
  → **stable operation of oxyfuel calcination achieved**
- Promising CO_2 concentrations at calciner outlet (>70%);

Residual difficulties in keeping **high sorbent circulation rates** for significant periods, due to small pilot ducts



Thanks for your attention!

For any question:

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