University of Stuttgart
Institute of Combustion and Power Plant Technology
Prof. Dr. techn. G. Scheffknecht

Accelerating Carbon Capture using Oxyfuel Technology in Cement Production

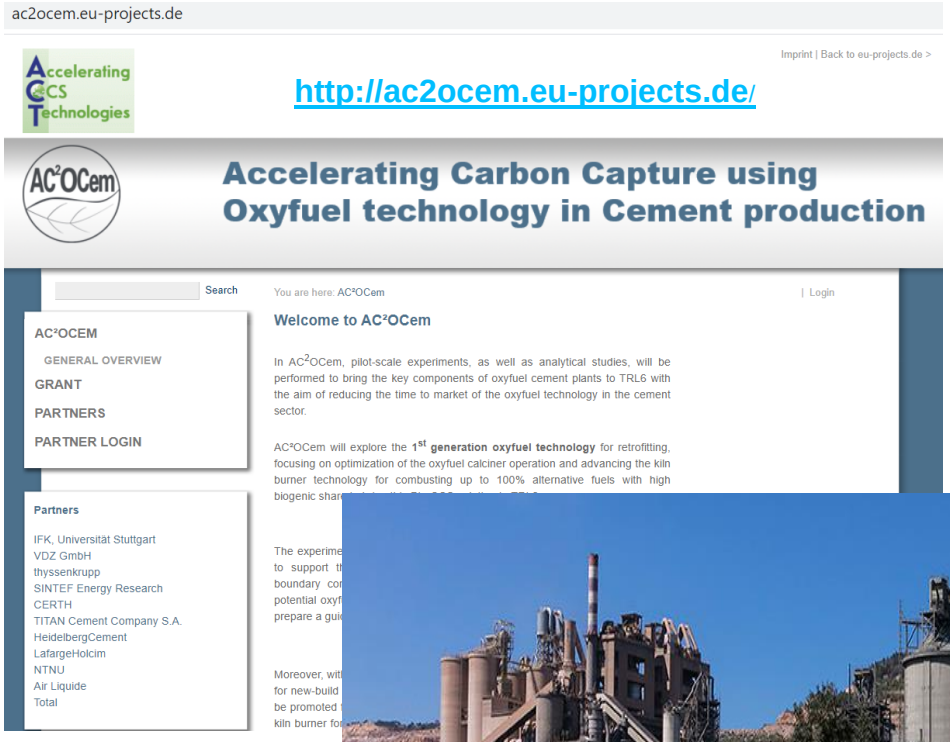
ACT Knowledge Sharing Workshop

Dipl.- Ing. Jörg Maier

17.11.2020, Stuttgart

Introduction to AC²OCem

Summary



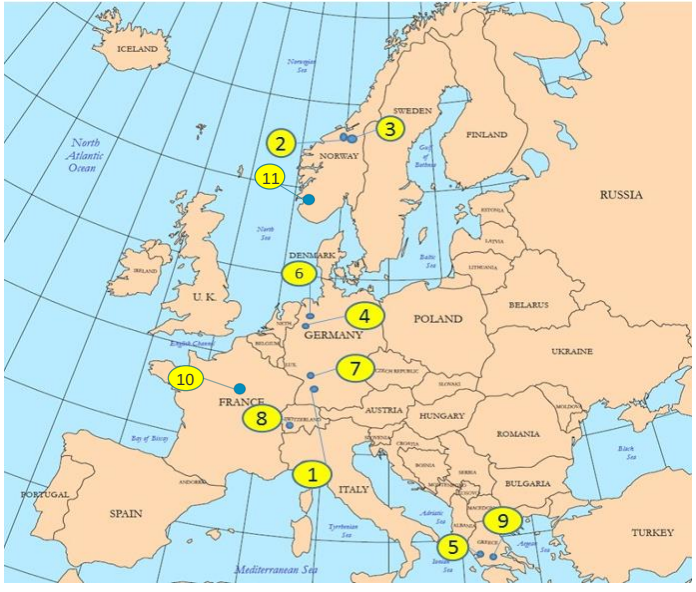
Project Duration	**36 months**
Start	**1.10.2019**
ACT Project No.	**299663**
ACT funding	**€ 3.042.274**
Total funding	**€ 4.273.911**

https://www.titan.gr/en/newsroom/media-library/photos

AC²OCem Consortium

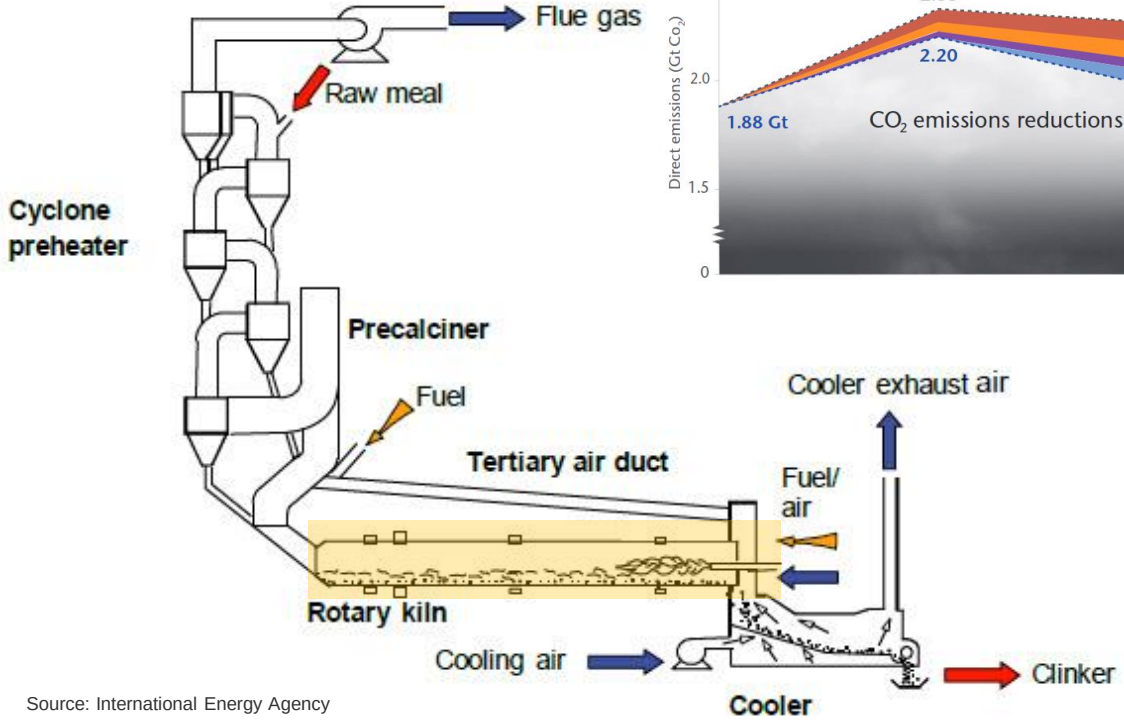
11 Project Partners from 5 European Countries

1. Universität Stuttgart, Germany
2. SINTEF Energy Research, Norway
3. Norwegian University of Science and Technology NTNU, Norway
4. VDZ GmbH, Germany
5. Center of Research and Technology CERTH, Greece
6. thyssenkrupp Industrial Solutions AG, Germany
7. HeidelbergCement AG, Germany
8. LafargeHolcim, Switzerland
9. TITAN Cement Company S.A, Greece
10. Air Liquide, France
11. Total Norge AS, Norway

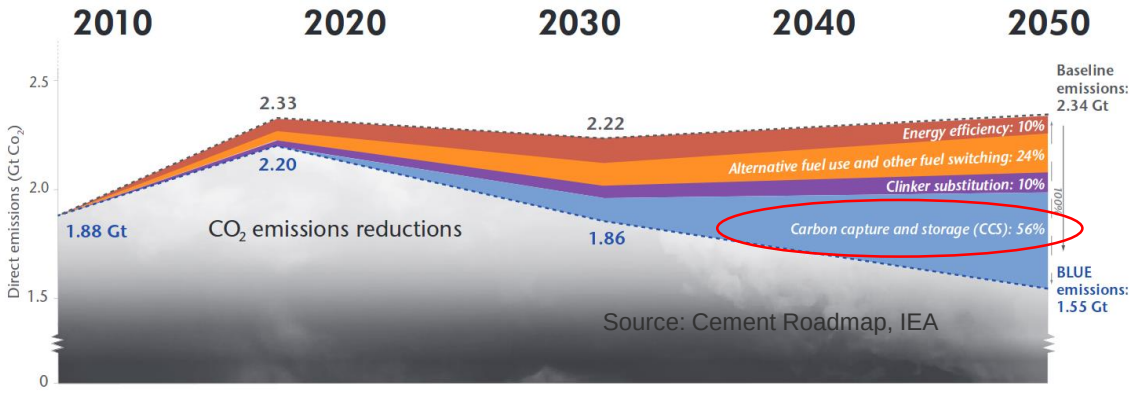


Motivation

50% of CO_2 => decomposition of limestone



Source: International Energy Agency

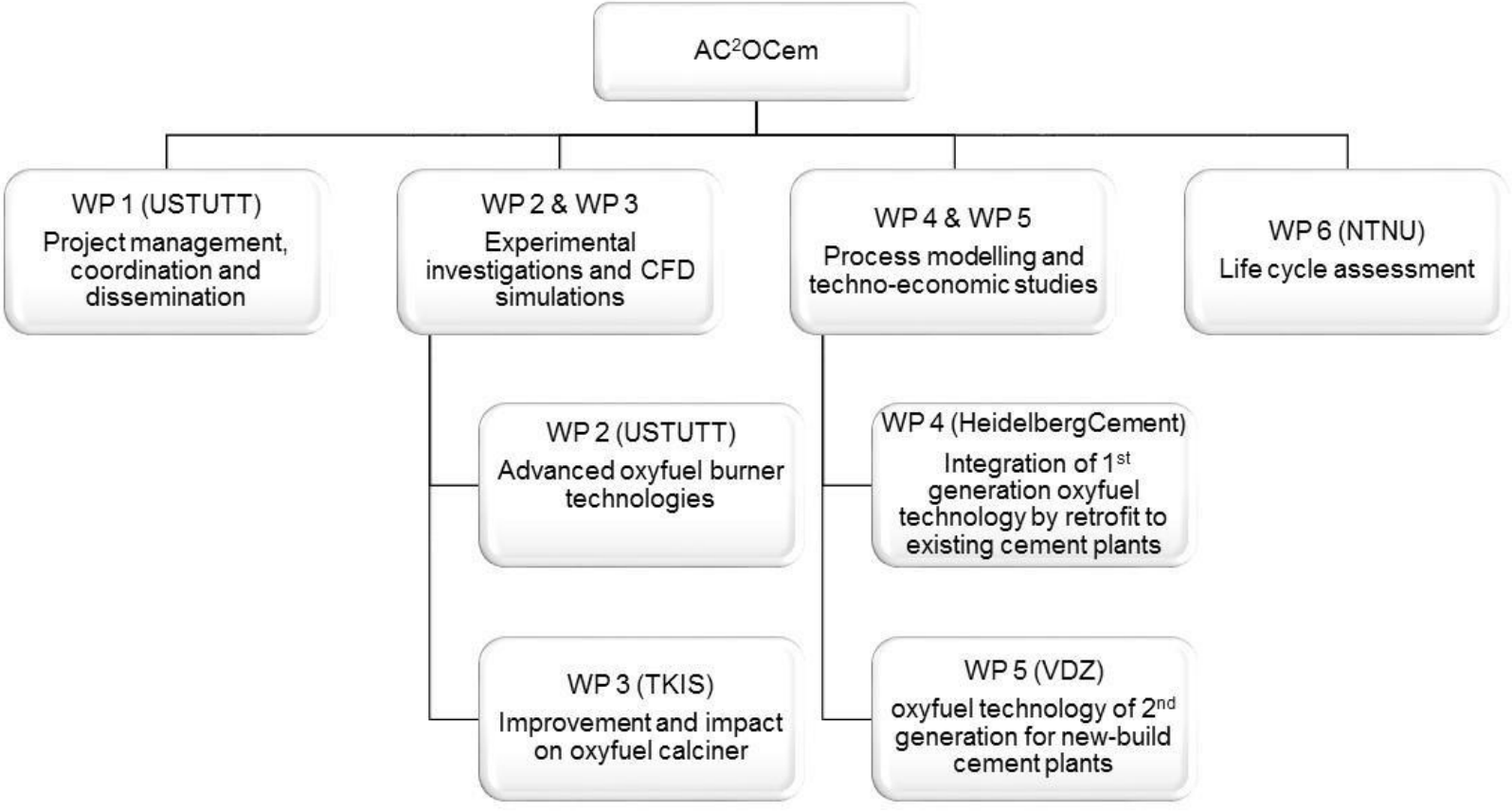


1 ton of cement → 0,6 - 0,7 tons of CO_2

AC²OCem Project Objectives

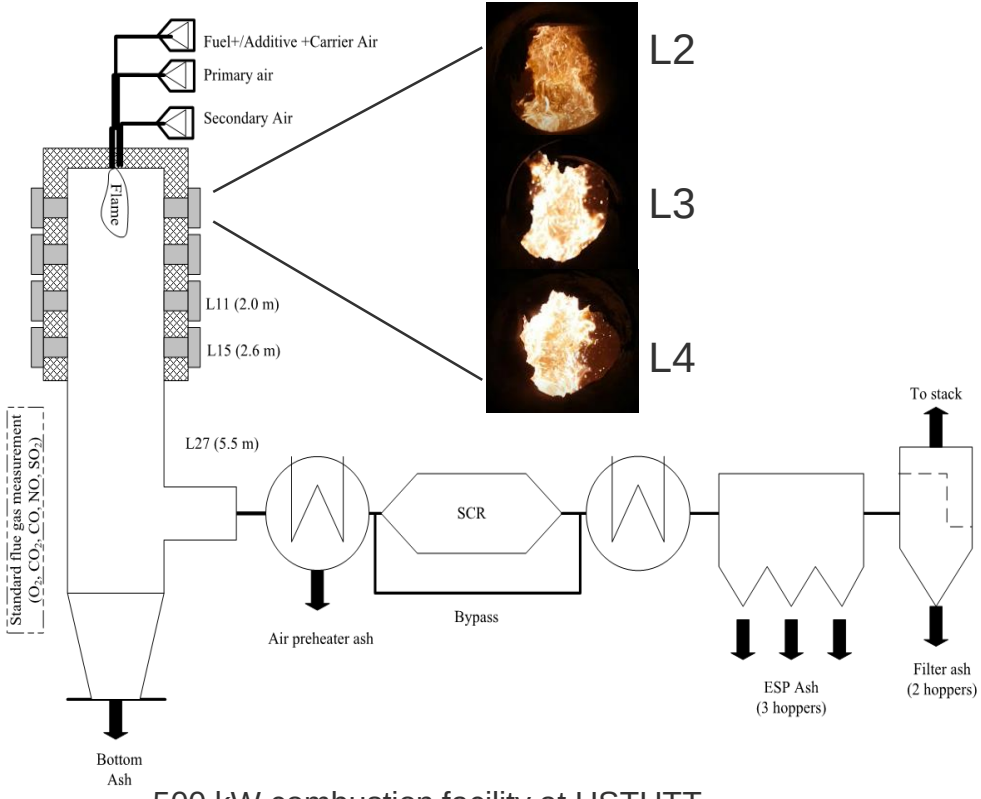
- Optimization of the oxyfuel cement process with the ultimate goal of **lowering the CO_2 avoidance cost**
- Advancing the 1st & 2nd generation oxyfuel technology for utilization **of up to 100% alternative fuels and up to 100 % oxygen**, respectively, boosting CO_2 negative cement plants (**Bio-CCS**).
- **Techno-economic analysis** and **design optimization** of two **1st generation cement plants**, LafargeHolcim in Lägerdorf, Germany and HeidelbergCement in Slite, Sweden.
- Experimental and analytical investigations of the **2nd generation oxyfuel technology without flue gas recycle**, associated with a high reduction potential of energy demand, **CAPEX and OPEX**

AC²OCem work package structure



Combustion tests with 100 % SRF at USTUTT

Task 2.1



500 kW combustion facility at USTUTT

Planned operational conditions

100 % SRF	100 % SRF	100 % SRF	100 % SRF
Air	OXY 27	OXY 33	OXY 41
300 kW	300 kW	300 kW	300 kW
λ = 1.15	λ = 1.15	λ = 1.15	λ = 1.15

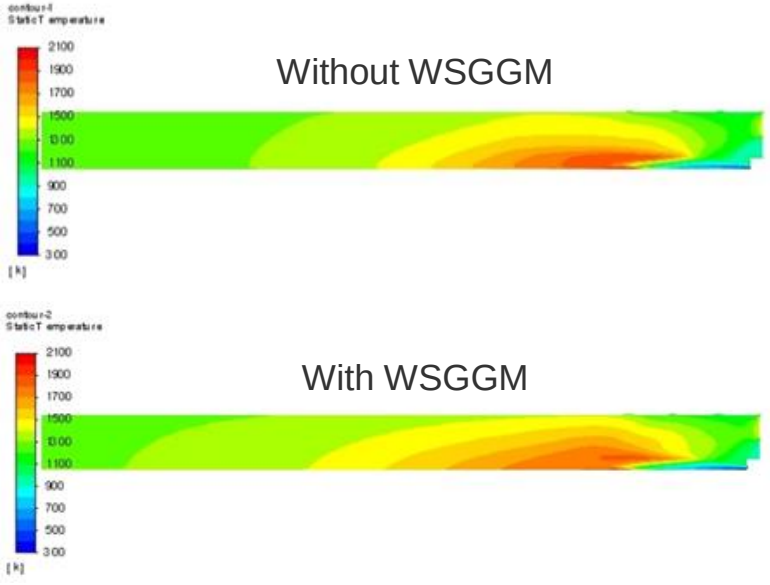
Next step: experimental campaign with 100% SRF at USTUTT

→ results will be used to validate the CFD simulation models of the combustion by CERTH/ SINTEF

CFD preliminary work by SINTEF and CERTH

- Included an UDF (WSGGM) for computing the absorbtion coefficients to the model used in CEMCAP (Stuttgart furnace). A line by line based weighted sum of gray gas model for inhomogeneous CO2-H2O mixture in oxy-fired combustion
- Checked the dependency of grid. Total number of cells varied from 223k to 2599k
- Inlets changed from mass flow to velocity inlets
- **Next step**: Modelling of the pilot plant with pure O2 on the current burner dimension

Temperature fields

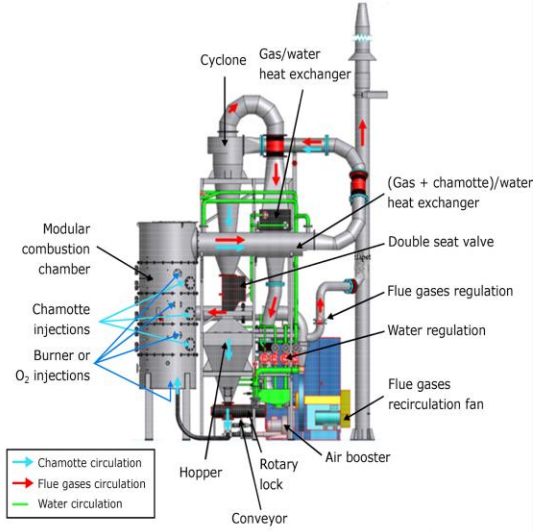


WP 3 Calcination tests under Oxyfuel Conditions

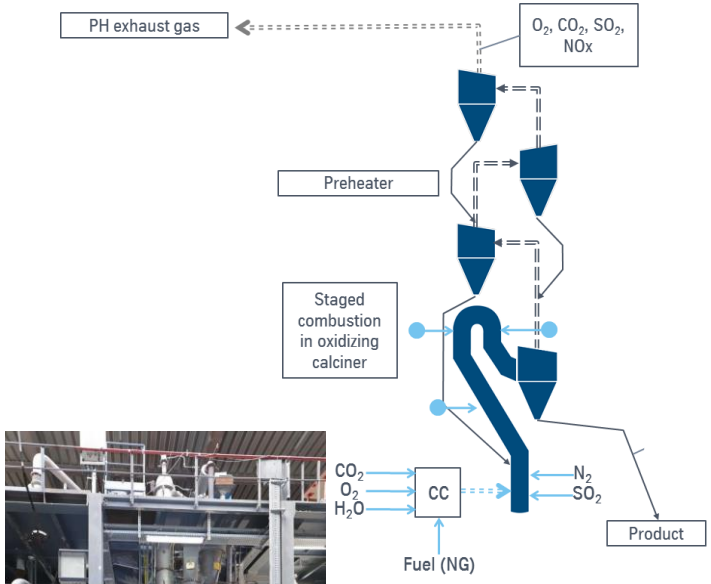
- Laboratory calcination Test in USTUTT started and ongoing

Next step:

- AL will start the pilot scale experimental testing in the 1 MW calciner with 100% alternative fuel in the calciner in December
- TKIS will start pilot scale experimental testing in oxyfuel conditions in the calciner in Janury 2021



Calciner test furnace of AL



Pilot-scale calciner and 4 stage pre-heater - tkIS

Integration of oxyfuel technology in existing cement plants (1. Generation)

Work package 4

(**VDZ**, CERTH, SINTEF, HeidelbergCement, LafargeHolcim, TITAN, TKIS, TOTAL, AL)

- Design considerations for retrofitted oxyfuel cement plants (with reference to the BAT)
- Process modelling and simulation of oxyfuel retrofitted cement plants considering several scenarios for flue gas recirculation
- **Results of task 4.1**

✓ A steady-state process model has been setup in ASPEN PLUS based on design and operating data of a reference 3000 t/d BAT plant.

✓ The simulation is aligned with VDZ's BAT model [1] to ensure consistency.
→ Good agreement of numerical results with the reference values.

Results Comparison (task 4.1)

Gas : Exhaust [moles %]

	CO_2	H_2O	N_2	O_2	S
BAT VDZ	31.9	5.1	59.0	3.3	0.0
CERTH	31.4	5.7	58.8	3.6	0.0

Product: Clinker [wt %]

	C_4AF	C_3S	C_3A	C_2S	CaO
BAT VDZ	8.8	65.8	10.2	14.3	0.8
CERTH	9.3	64.4	8.2	12.0	1.6

[1] CEMCAP, D4.1 "Design and performance of CEMCAP cement plant without CO2 capture" https://www.sintef.no/globalassets/sintef-energi/cemcap/d4.1-cemcap-cement-plant-without-co2-capture_rev2.pdf/

Integration of retrofit oxyfuel cement plants

Work package 4

Next step:

→**VDZ/CERTH** Simulation based on boundary conditions provided by **Industrial Partner** to assess oxyfuel scenarios and create a separate model for simulating the CO_2 processing unit (CPU).

→Investigate various oxyfuel scenarios.

→Assessment of flue gas impurities and waste process streams in CPU operation

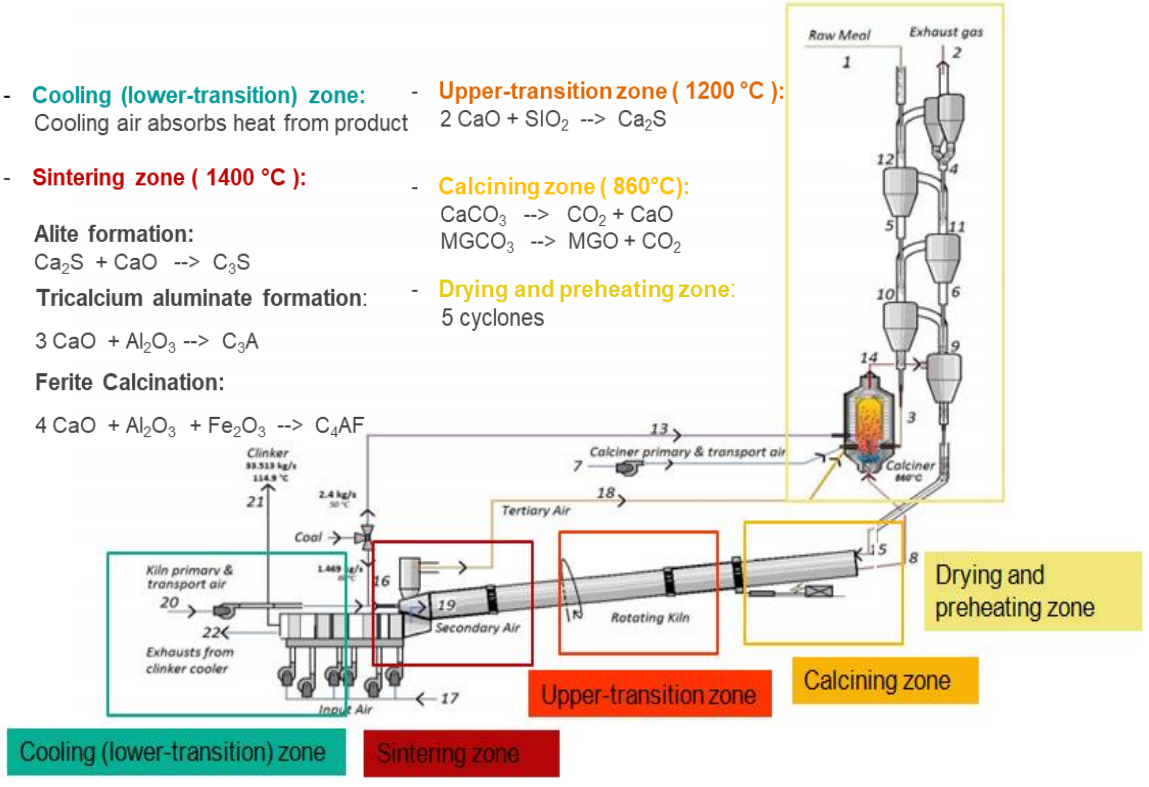
- **Cooling (lower-transition) zone:**
  Cooling air absorbs heat from product
- **Sintering zone (1400 °C):**

Alite formation:
$Ca_2S + CaO \rightarrow C_3S$

Tricalcium aluminate formation:
$3\,CaO + Al_2O_3 \rightarrow C_3A$

Ferite Calcination:
$4\,CaO + Al_2O_3 + Fe_2O_3 \rightarrow C_4AF$

- **Upper-transition zone (1200 °C):**
  $2\,CaO + SiO_2 \rightarrow Ca_2S$
- **Calcining zone (860°C):**
  $CaCO_3 \rightarrow CO_2 + CaO$
  $MGCO_3 \rightarrow MGO + CO_2$
- **Drying and preheating zone:**
  5 cyclones



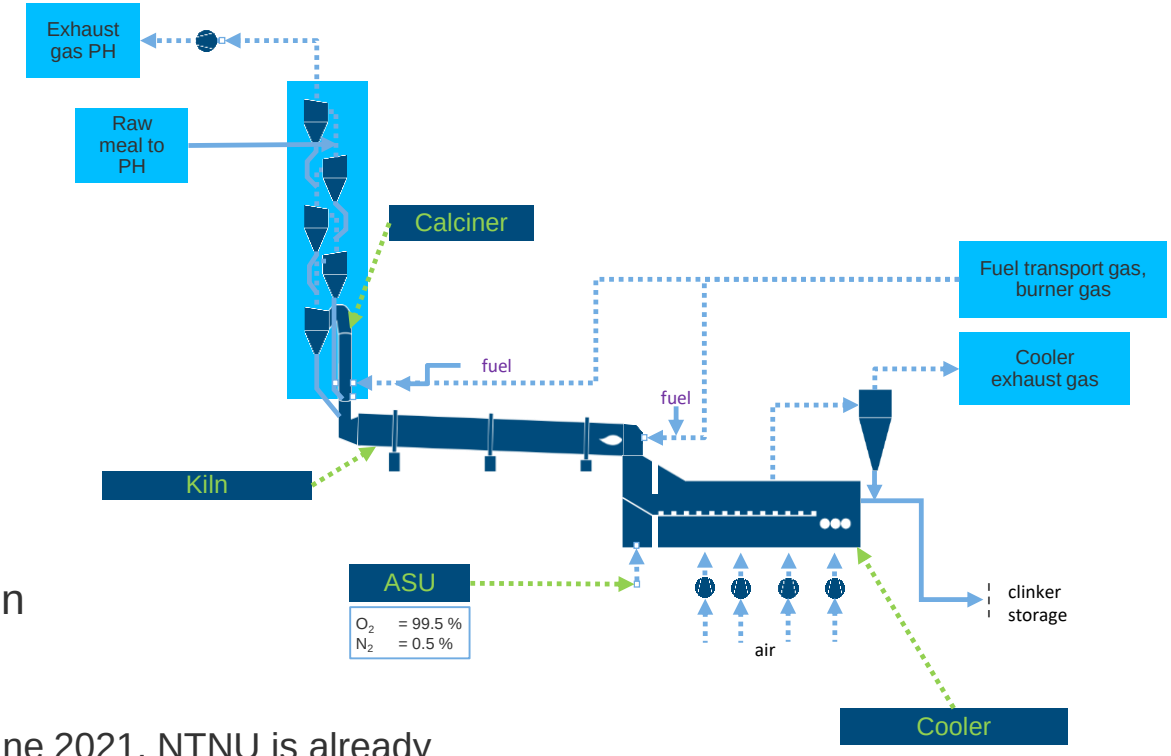
Summary WP 5/6

Objectives

- Optimization of the design and infrastructure for new-build plants.
- Evaluation of techno-economic feasibility of new-build oxyfuel cement plants.

Next step: activity in WP 5 has begun for the preliminary design considerations of oxyfuel operation

Oxyfuel 2nd genenation process scheme



WP6 LCA Next step: WP 6 starts in June 2021, NTNU is already busy with literature study and pre-organization of information for the environmental impact and life cycle analysis

Next steps

Staying in contact during the pandemic

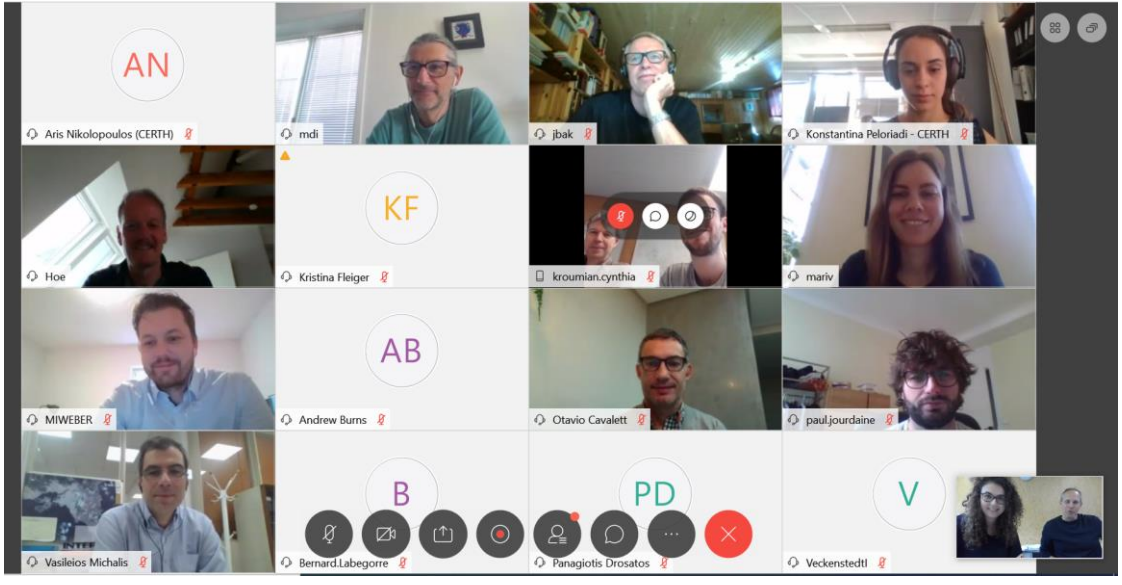
… what our meetings look like today

- Unfortunately, the pandemic happened in a time frame heavy with experimental activities
  → some experiments are postponed due to safety measures

- The consortium partners are working together to abate any further delays by starting simulation tasks earlier than planned

→this helps keep the project on track and insures CCS research is accelerate!

→Next progress meeting in January 27 & 28, 2021



- **Excellent Project Team**

Thank you to our funding agencies

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- Research Council of Norway, (RCN), Norway
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- Swiss Federal Office of Energy (SFOE), Switzerland
- General Secretariat for Research and Development (GSRT), Greece
- French Environment & Energy Management Agency (ADEME), France

University of Stuttgart

Thank you!

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Accelerating CCS Technologies

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