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

AC²OCem

Accelerating CCS Technologies

Accelerating Carbon Capture using Oxyfuel Technology in Cement Production

ACT Knowledge Sharing Workshop

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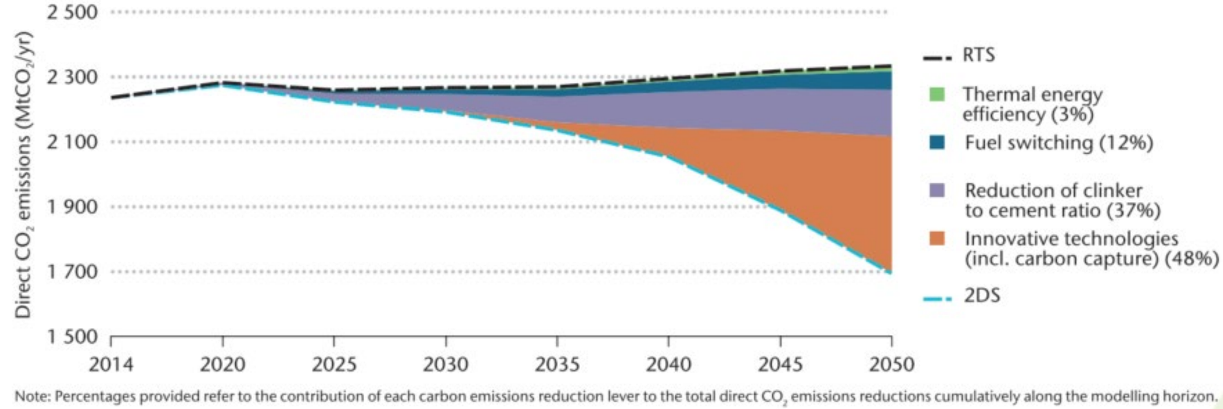
09.06.2022, Rotterdam

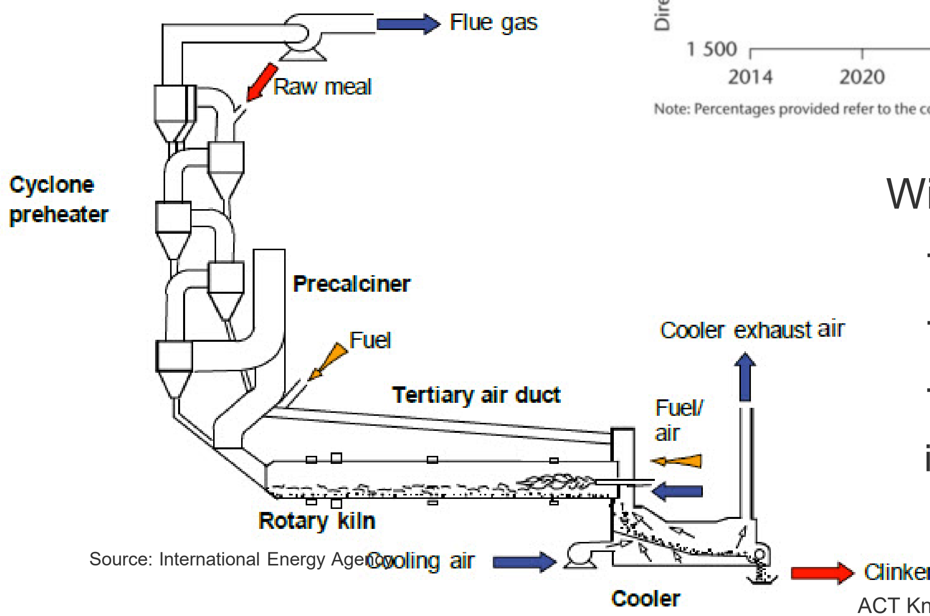
ifk

AC²OCem project motivation

1 ton of cement → 0.6 – 0.7 tons of CO_2

2/3 of CO_2
⬇
decomposition of limestone





Source: International Energy Agency

Without **CCUS** in the cement industry

→ Carbon neutrality can not be reached by 2050

→ A sustainable future cement production is not possible

→ Threat to 1 million jobs in the cement and concrete industry Europe wide

AC²OCem Consortium

Academic and research institutes

University of Stuttgart Germany, ifk, SINTEF, vdz., CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS, NTNU

Industry end-users

LafargeHolcim, HEIDELBERGCEMENT, TITAN, TOTAL

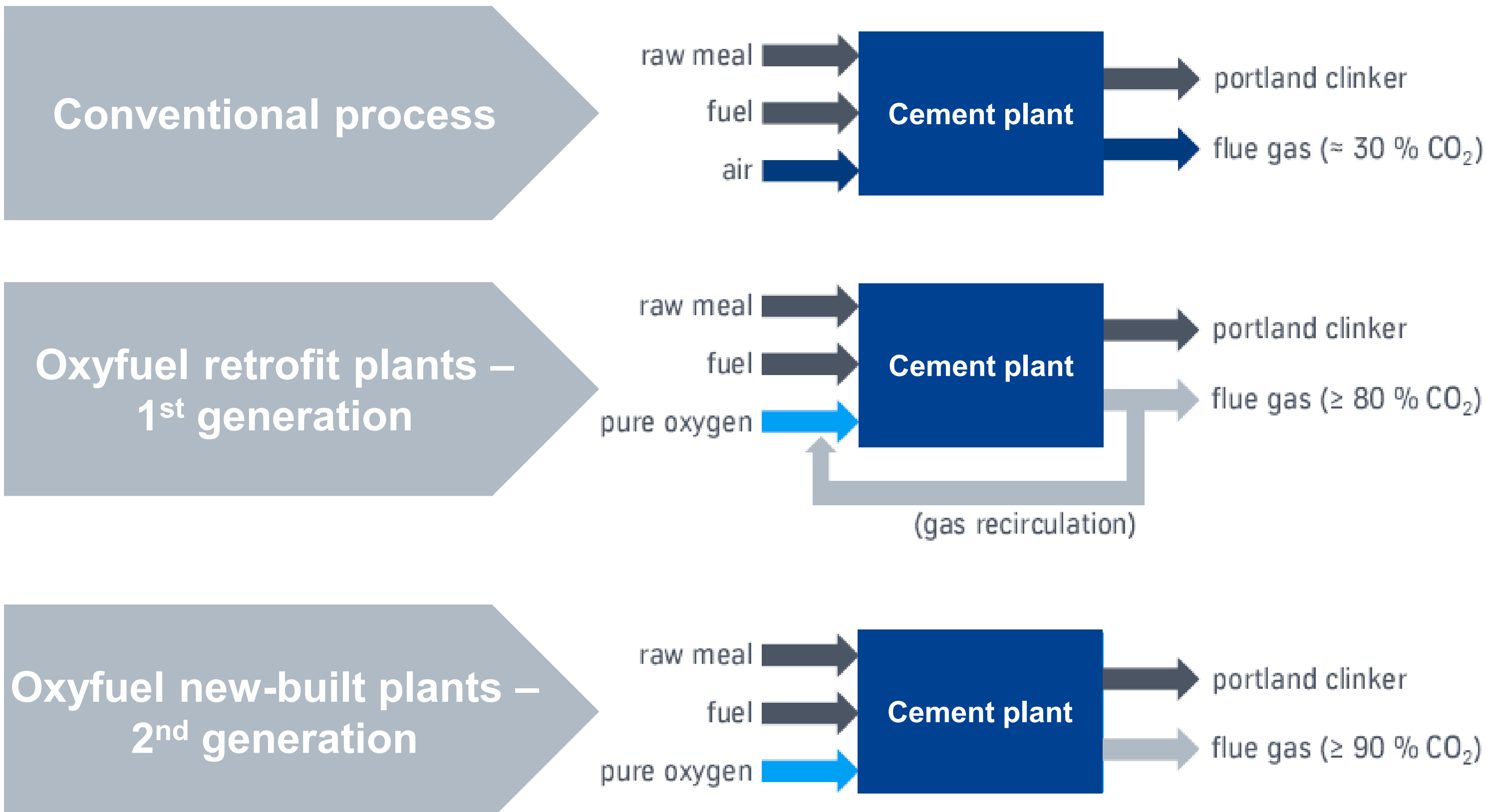
Technology providers

Air Liquide, thyssenkrupp

Project Duration	36 + 6 months
Start	1.10.2019
ACT Project No.	299663
ACT funding	€ 3.042.274
Total funding	€ 4.273.911

Oxyfuel technology in the cement industry

Retrofit and new-built plants

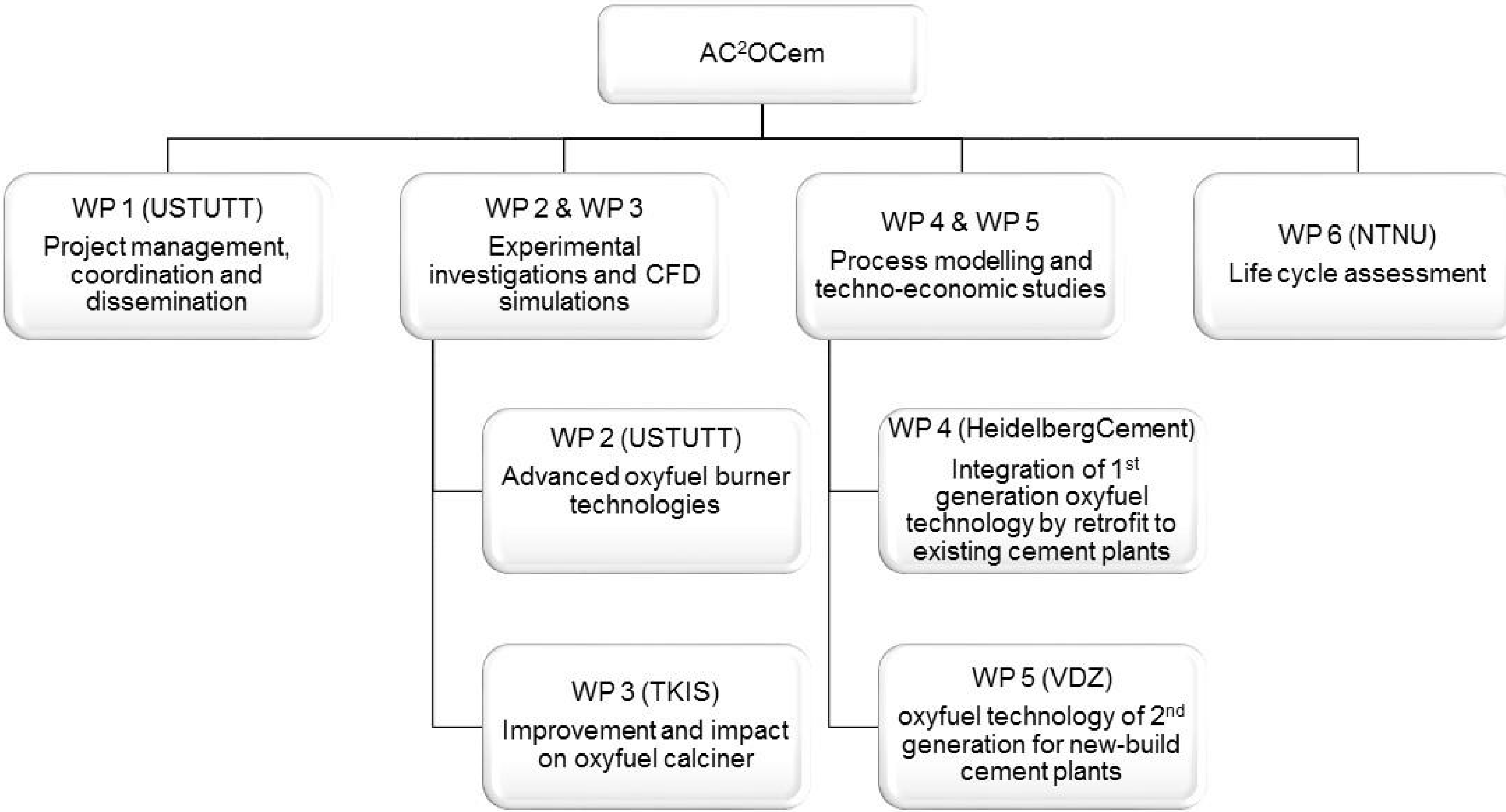


Source: adapted from: TKIS, VAIS Webinar 2021

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 **1st generation** cement plants, based on boundary data from Holcim 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



Pilot-scale experiments with 100 % alternative fuel and 100 % oxygen

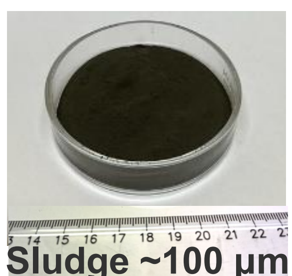
WP 2

100 % alternative fuel

SRF
- Air
- OXY31
- OXY37

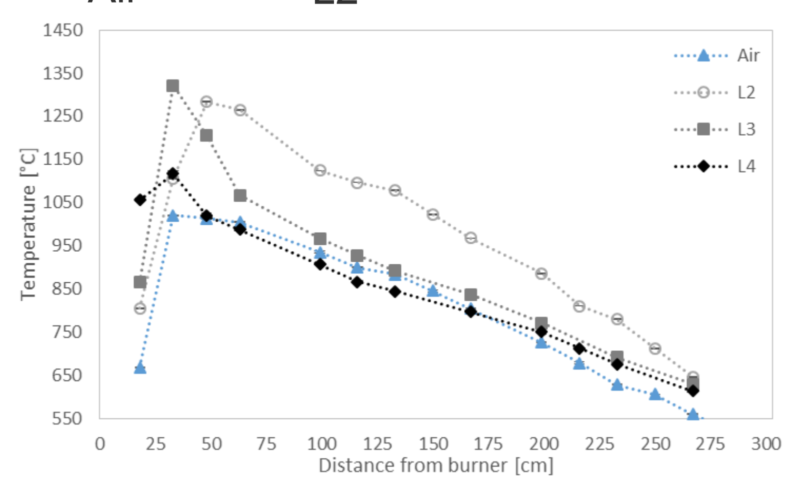
Wood
- Air
- OXY31
- OXY38

Wood + Sludge
- Air
- OXY33
- OXY39



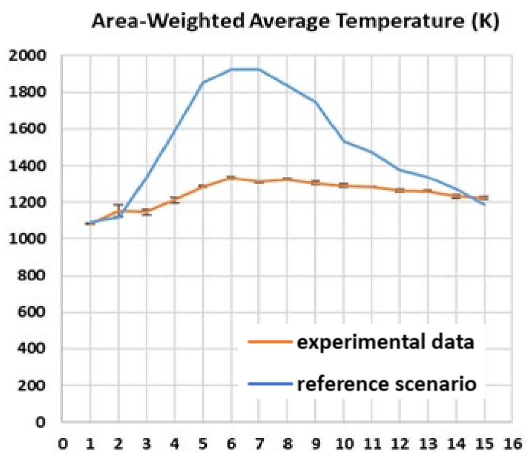
100 % oxygen tests

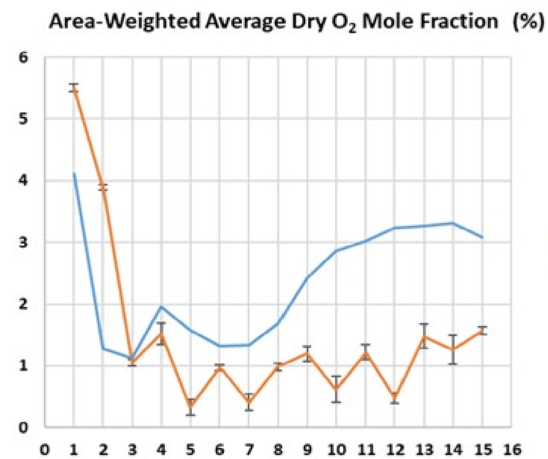
Air L2 L3 L4

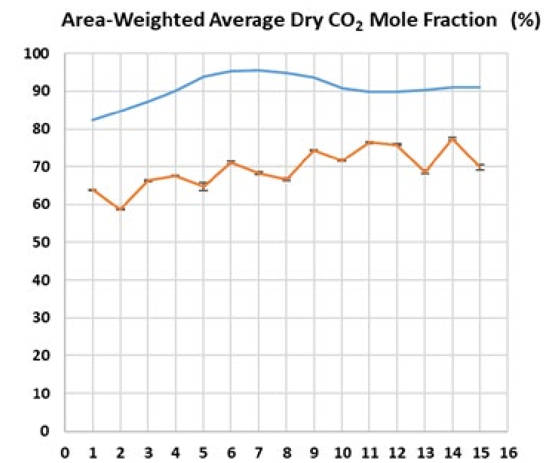


CFD preliminary work by SINTEF and CERTH – SRF OXY31

WP 2







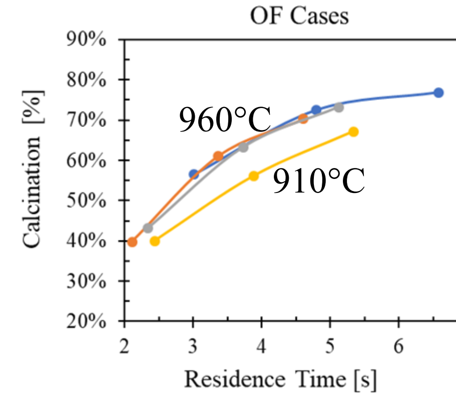
100 % SRF combustion in oxyfuel conditions

- 100 % SRF was combustion in the 500 kW combustion chamber at the University of Stuttgart
- The CFD model approximates the reference values for all the three main parameters and the flow is fully developed and is verified using the experimental data

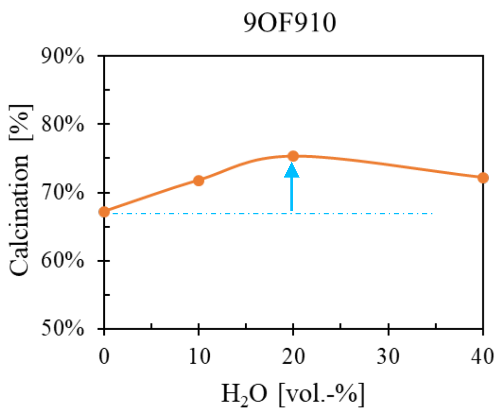
Improvement and impact on oxyfuel calciner

WP 3

- **Temperature** shift caused by oxyfuel atmosphere confirmed
- Role of **moisture** is evaluated. Threshold of moisture level regarding positive influence.
- The impact of **impurities** on deposit build-up is evaluated. KCl and SO2 doped as impurities.



Oxy fuel (OF) Cases



Influence of moisture

Atmosphere	Average calciner temperature - °C	Moisture content at calciner outlet - %
Air (reference case)	840/870/910	15 – 21 - 26
Oxyfuel *) (O_2/ CO_2)	910/ 940/ 960	
Air/ Oxyfuel *) + SO_2	920-930	23
Oxyfuel*) + N_2	940	23

Retrofitting Oxyfuel 1st generation to existing plants

WP 4

Main differences of the selected plants is the raw material moisture and the need for drying energy

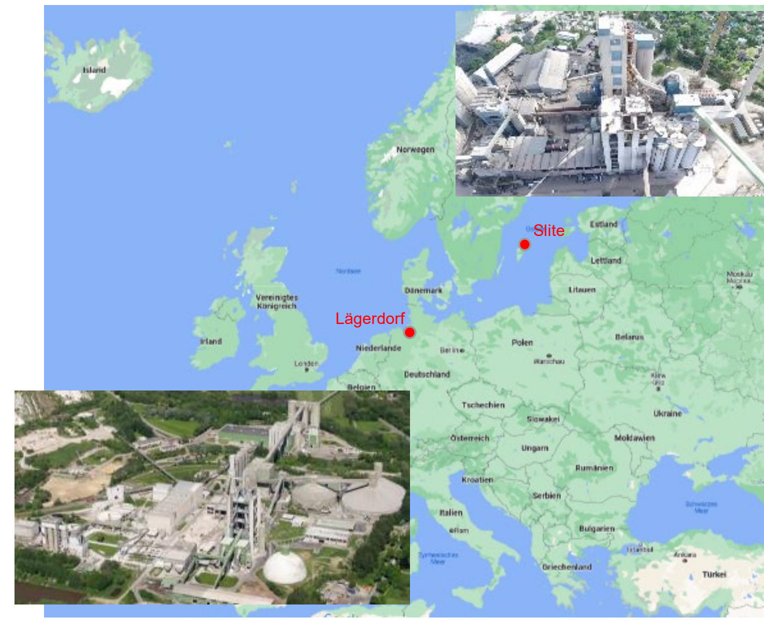
- Lägerdorf: Semi-wet process (~ 20% moisture)
- Slite: Dry process (2-3% moisture)

Design considerations

- Lägerdorf: Integration of raw material dryer
- Slite: Management of impurities (esp. SOx)

Process modelling

- Recirculation rate depending on given plant geometry and the need for excess heat
- CO_2 concentration in both cases ~ 80 %



Retrofitting Oxyfuel 1st generation to existing plants

WP 4

Heat integration

- Lägerdorf: Intensive heat exchanger network necessary to provide enough energy for drying
- Slite: Simplified heat exchanger network and generation of power possible

Main technical challenges identified

- Lägerdorf: Heat integration based on decoupling material drying and kiln plant (with procedure for start-up)
- Slite: Integration of SOx scrubber required, limited space

Emission reduction potential

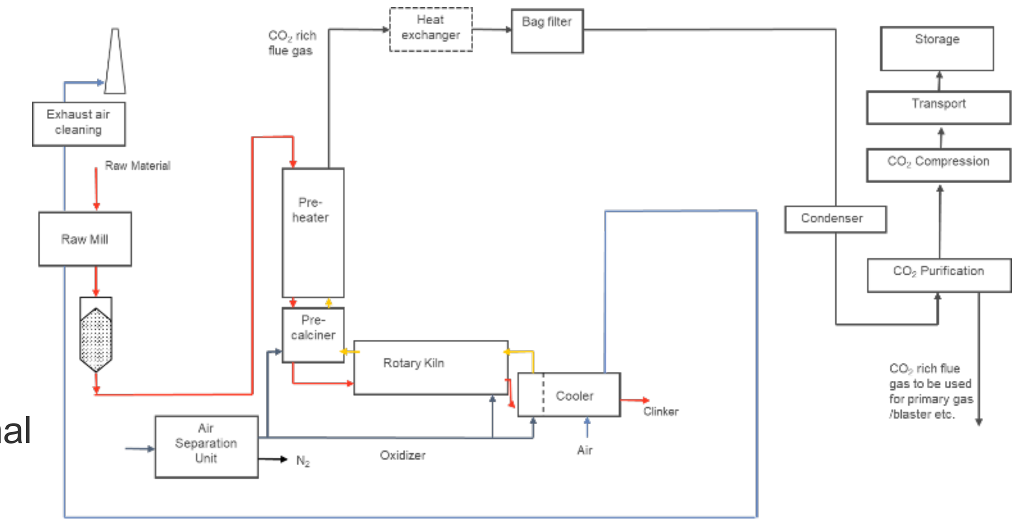
- Near zero emissions and 95% capture rate in the cement plant
- Negative CO_2 emissions in both cases possible according to biogenic CO_2 from the use of alternative fuels and long-term storage

Design of 2nd generation oxyfuel kiln

WP 5

Main characteristics

- No flue gas recirculation
- Combustion in pure oxygen
- Gas volume flows are decreased



Objectives

- Design development: 2 configurations
- Process modelling: Identification of optimal operational mode
- Heat integration: Heat exchanger network for optimal excess heat use

Deliverables

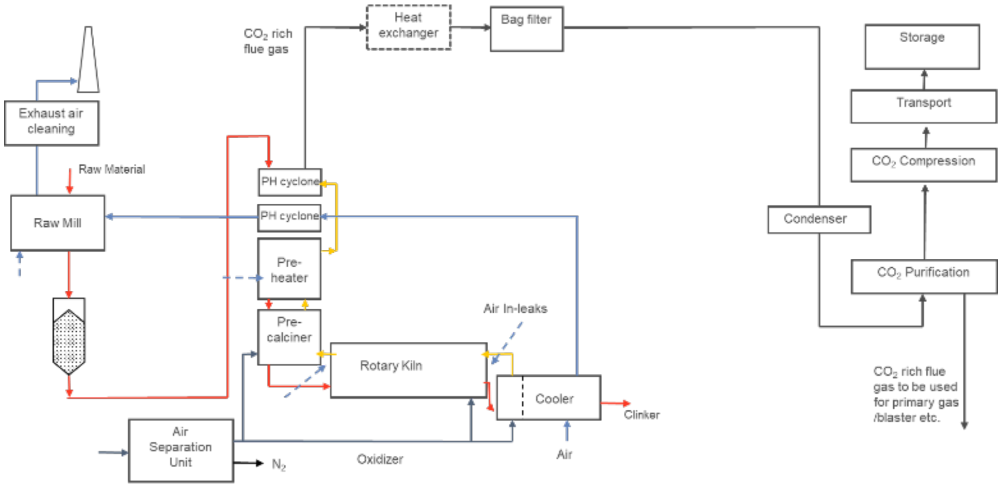
- Techno-economic feasibility study of 2nd gen. oxyfuel cement plant
- Techno-economic comparitive study of 1st and 2nd gen. oxyfuel cements plants

Design of 2nd generation oxyfuel kiln

WP 5

Preliminary results

- Thermal energy demand strongly depends on preheating of the material and correspondingly on flue gas volume
- Use of alternative fuels beneficial with regard to thermal energy demand (compared to air fired AFR case)
- Second configuration includes air stage to support material preheating
- Slightly lower power demand than Oxyfuel 1Gen due to higher CO_2 concentration up to 90 vol.%
- High potential for power generation (to cover approx. 25% of the additional power demand)



LCA of retrofitted cement plants under oxyfuel conditions at high biogenic fuel shares

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WP 6

- Life cycle assessment based on real-world data of two cement plants operating under **conventional and retrofitted to oxyfuel CCS conditions** are **benchmarked with a reference cement** plant.
- Quantification of impacts on **climate change (various climate metrics), human toxicity, fossil depletion potential and water depletion potential**.
- **Increasing use of alternative fuels** with high share of **biomass** (up to 100%) in the cement plants operating under oxyfuel conditions.
- Impacts with use of biomass from both **dedicated energy crops and forest residues**.
- **Prospective LCA** considering the **projected changes in the electricity systems** in the two respective countries created with a forward-looking background life-cycle database**.**

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Check for updates

OPEN

LCA and negative emission potential of retrofitted cement plants under oxyfuel conditions at high biogenic fuel shares

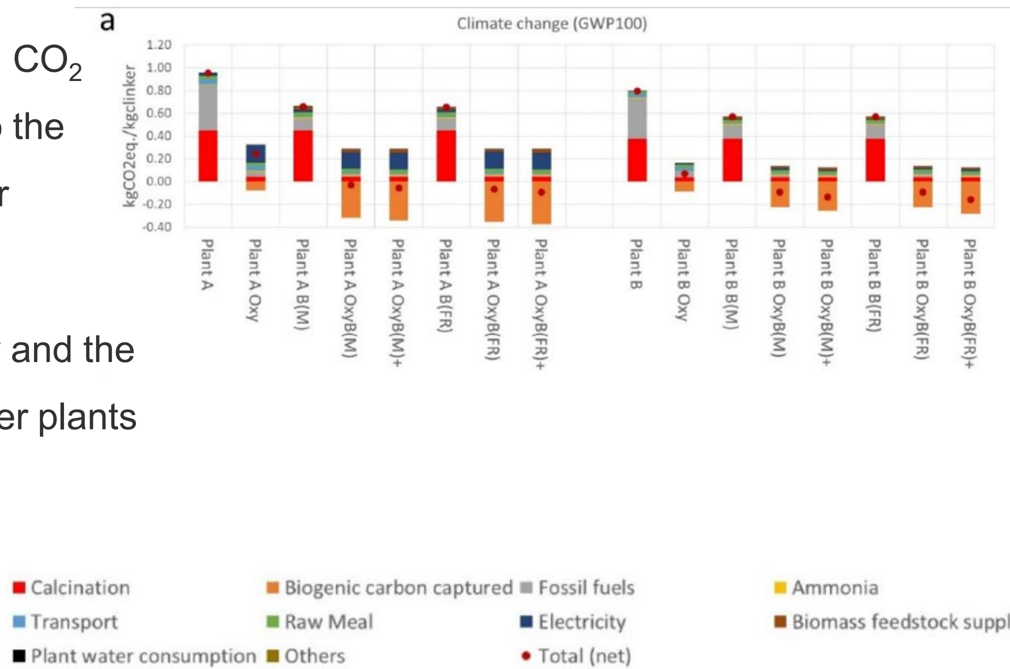
Otavio Cavalett[1]✉, Marcos D. B. Watanabe[1], Kristina Fleiger[2], Volker Hoenig[2] & Francesco Cherubini[1]

The implementation of oxyfuel carbon capture and storage technologies in combination with use of alternative fuels comprising high biogenic shares is promoted as an attractive climate change mitigation option for the cement sector to achieve low or even negative carbon emissions. Here, we perform a prospective life cycle assessment of two state-of-the art cement plants, one in Sweden and one in Germany, under conventional and retrofitted oxyfuel conditions considering alternative fuel mixes with increasing bio-based fractions of forest residues or dedicated bioenergy crops. The analysis also considers effects of the projected changes in the electricity systems up to 2050. Retrofitting the cement plants to oxyfuel reduces climate change impacts between 74 and 91%, while with additional use of biomass as alternative fuel the cement plants reach negative emission between −24 and −169 $gCO_{2eq.}\ kg_{clinker}^{-1}$, depending on operational condition, location, and biomass type. Additional emission reduction of −10 (Sweden) and −128 $gCO_{2eq.}\ kg_{clinker}^{-1}$ (Germany) are expected from the decarbonization of the future electricity systems. Retrofitting the cement plants to oxyfuel conditions shows trade-offs with other environmental impacts (e.g., human toxicity, water and energy depletion), which are partially offset with projected changes in electricity systems. Our results illustrate the large climate change mitigation potential in the cement sector that can be achieved by the implementation of oxyfuel carbon capture and storage and biomass use as alternative fuel.

Selected environmental impact categories with increased use of biomass

WP 6

- Higher biomass shares allows achieving negative emissions.
- Retrofitting the cement plants to the oxyfuel CO_2 capture technology show today according to the electricity mix in Europe trade-offs with other environmental impact factors.
- With increasing shares of renewable energy and the availability of Oxygen from the H_2 electrolyser plants the oxyfuel CO_2 capture technology will overcompensate such impacts substantially.

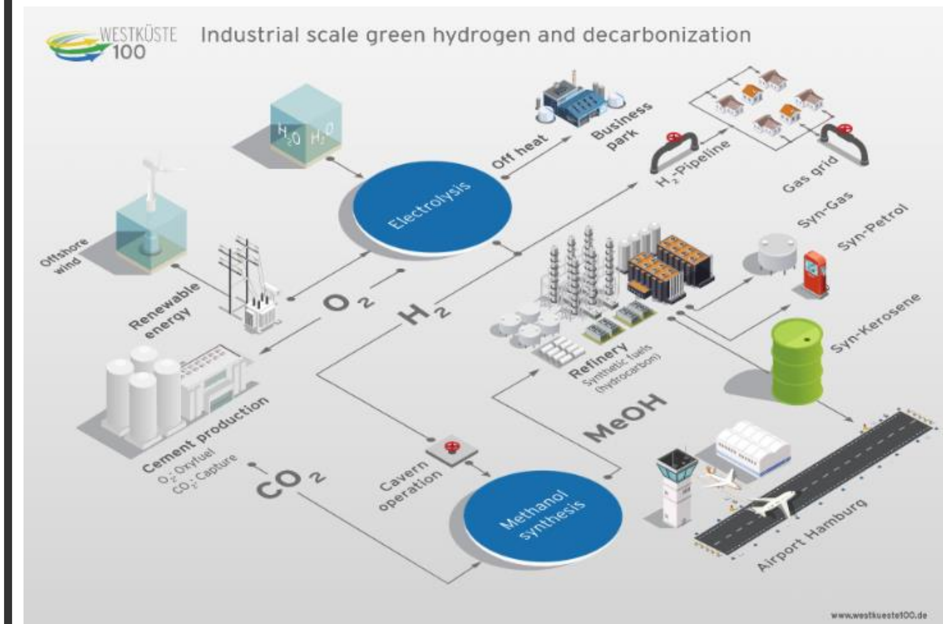


Chances for commercializing the oxyfuel technology…

… to accelarate CCUS in the cement industry

CI4C
CEMENT INNOVATION FOR CLIMATE

Source: Heidenheimer Zeitung, ‚Wie Schwenk Bürgerfragen zur geplanten Versuchsanlage in Mergelstetten beantwortet' 14.02.2022



WESTKÜSTE 100

Next steps for AC^2OCem

- Unfortunately, the pandemic happened in a time frame heavy with experimental activities
  → 6 months extension has been requested and granted
- Most experimental work has been completed, last tests planned for this summer.
- The consortium partners are working together to abate any further delays

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

→Next progress meeting November 2022

→Workshop, in collaboration with the ANICA project in March 2023

http://ac2ocem.eu-projects.de/

5th progress meeting in Holcim, Lägerdorf

Thank you to our funding agencies

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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

Thank you!

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Accelerating CCS Technologies

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