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

# Accelerating Carbon Capture using Oxyfuel Technology in Cement Production- AC²OCem

4th ACT Knowledge Sharing Workshop

7 November 2019, Athens

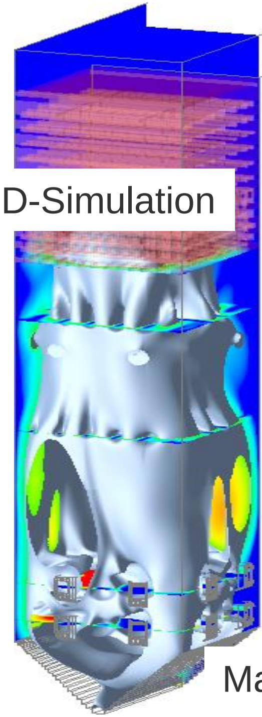
Dipl.-Ing. Jörg Maier

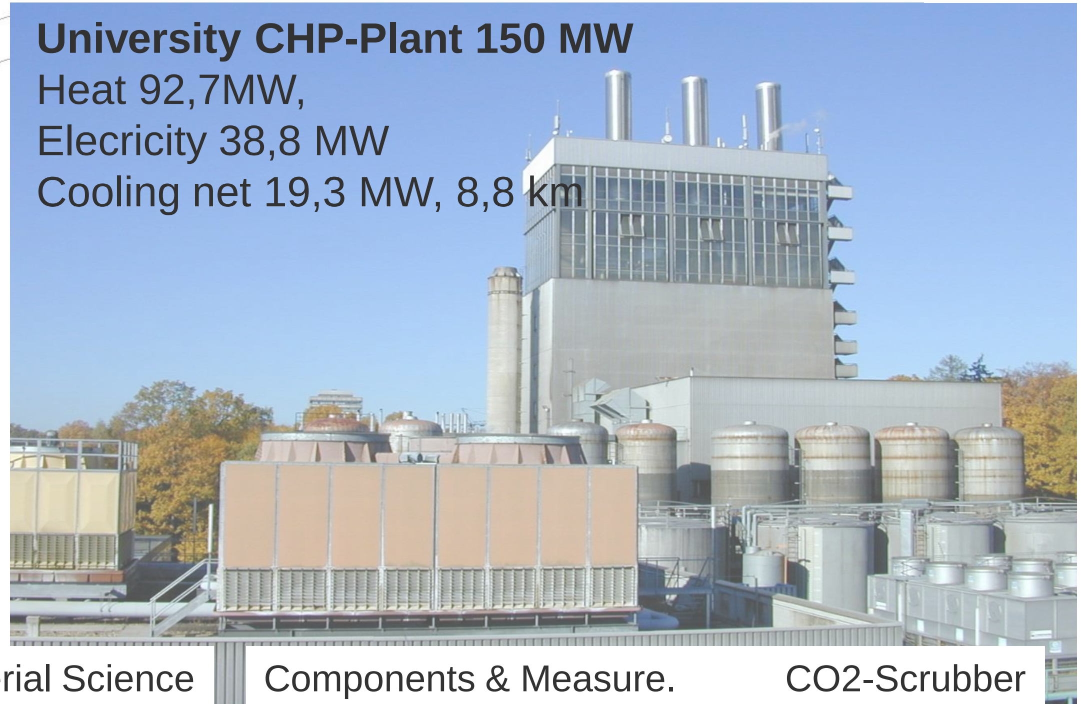
ifk

# Energy Infrastructure and Tools at IFK

University of Stuttgart
Germany

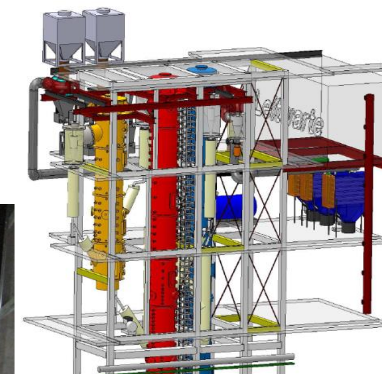
CFD-Simulation





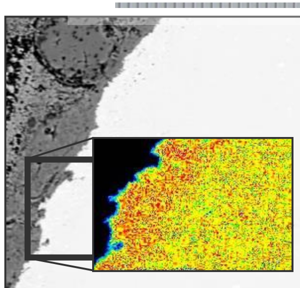
**University CHP-Plant 150 MW**
Heat 92,7MW,
Elecricity 38,8 MW
Cooling net 19,3 MW, 8,8 km

PC-Oxyfuel
500 $kW_{th}$



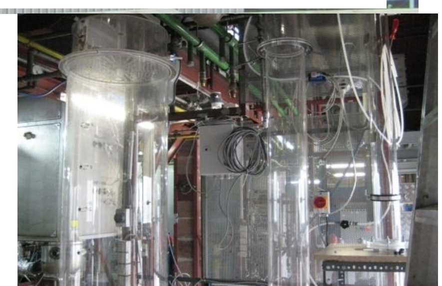
350 $kW_{th}$
Dual CFB system

Material Science



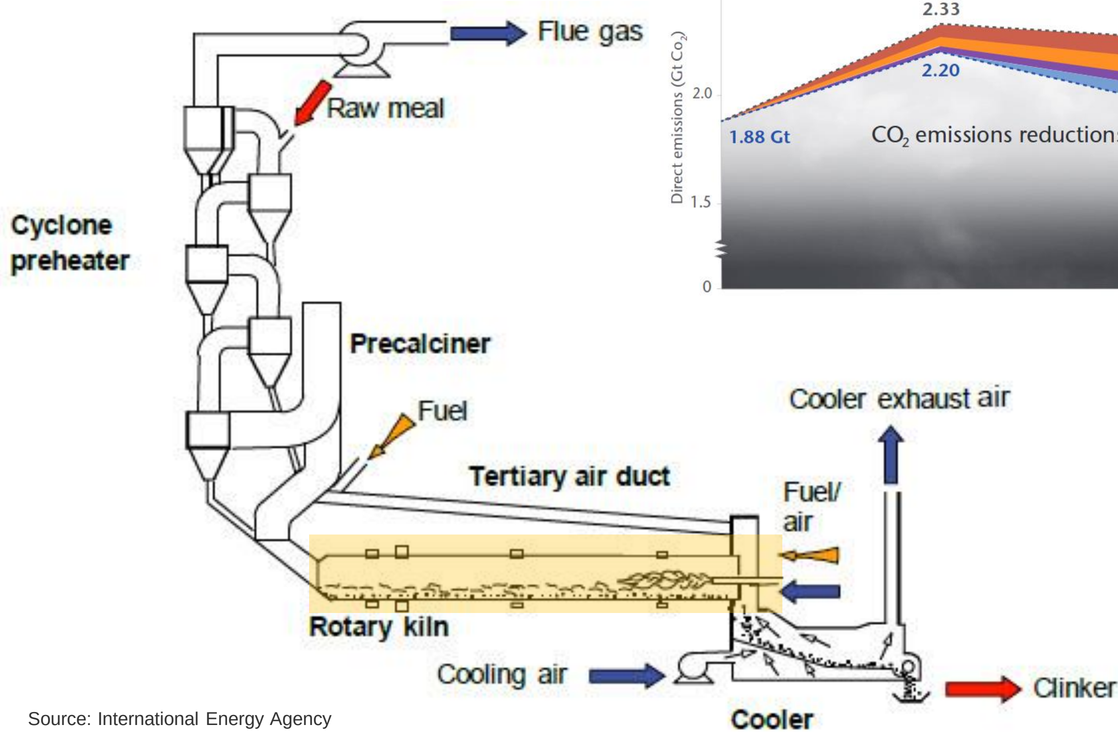
Components & Measure.

CO2-Scrubber

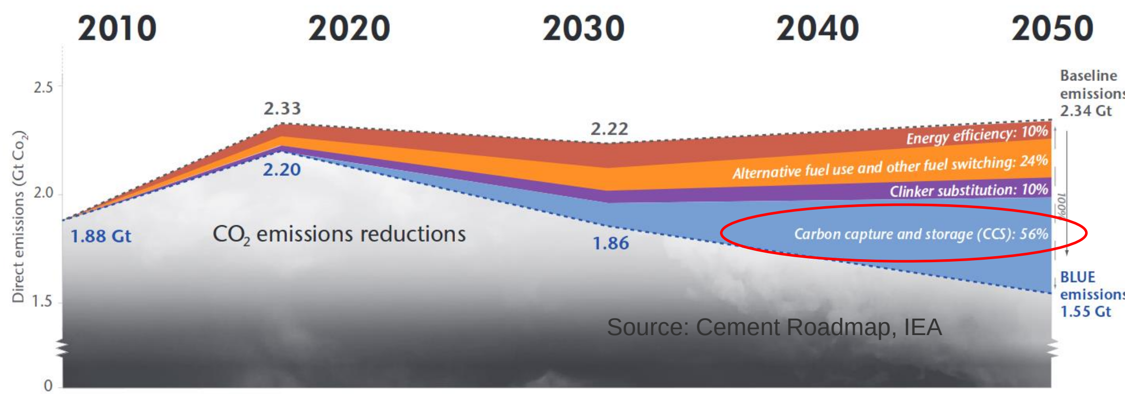


# Motivation

50% of $CO_2$ =>
decomposition of limestone



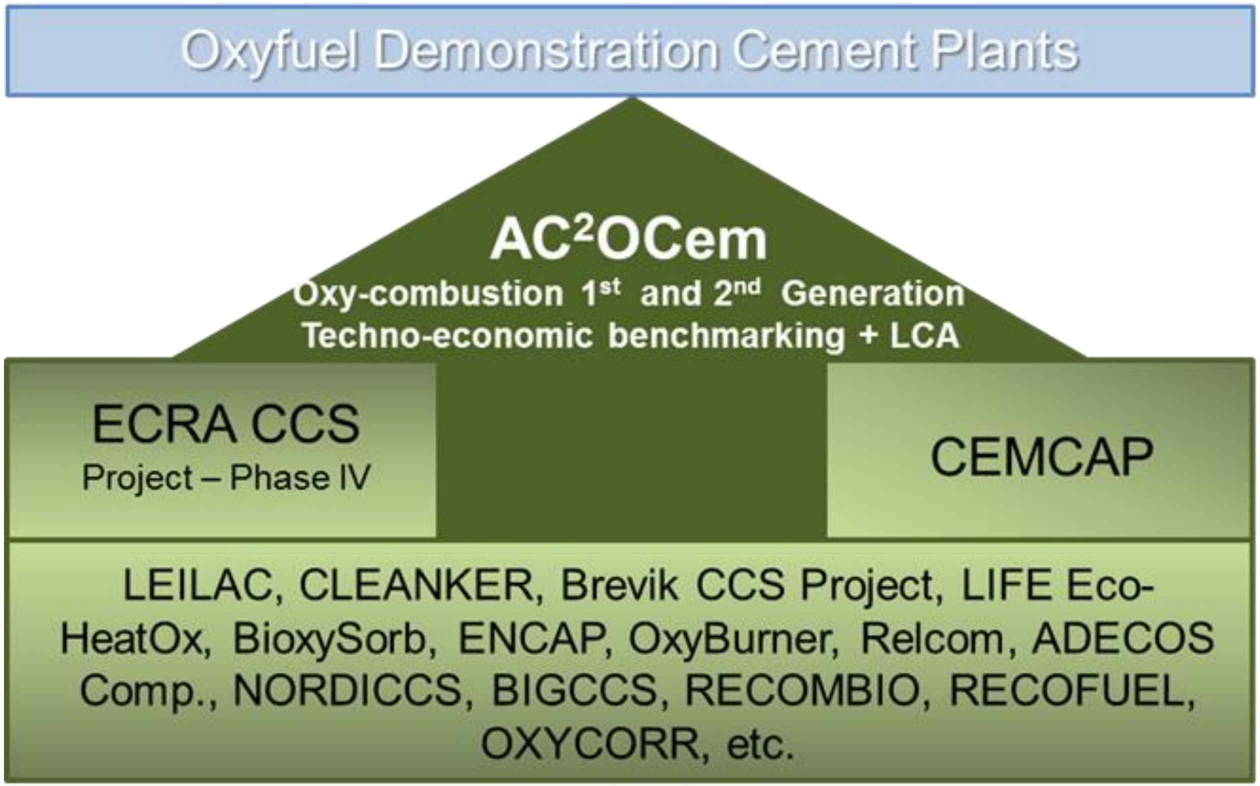

Source: International Energy Agency




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

# Recent research relevant to AC²OCem

## Relation to other CCUS and oxyfuel projects



# AC²OCem - Project Data

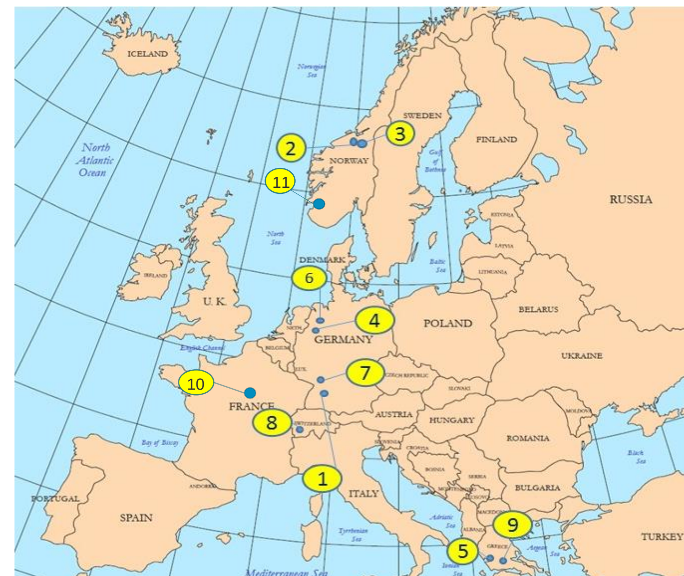
- Project name: **Accelerating Carbon Capture using Oxyfuel technology in Cement production**
- Project Duration: **36 months** (starting on 1 October 2019)
- ACT Project No.: **299663**
- Total budget: **4.273.911 euros**

| Financial source (in €) | |
|---|---|
| In-kind from project partners | **984.437** |
| Industry financial contribution | **247.200** |
| Applied Funding from national ACT bodies | **3.042.274** |
| **Total** | **4.273.911** |

- 11 Project Partners from 5 European Countries

# AC$^2$OCem Partners

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. L'AIR LIQUIDE, France
11. Total Norge AS, Norway




HEIDELBERGCEMENT

Air Liquide

LafargeHolcim

University of Stuttgart Germany

ifk

TOTAL

ThyssenKrupp

ThyssenKrupp Industrial Solutions

vdz.

NTNU

SINTEF

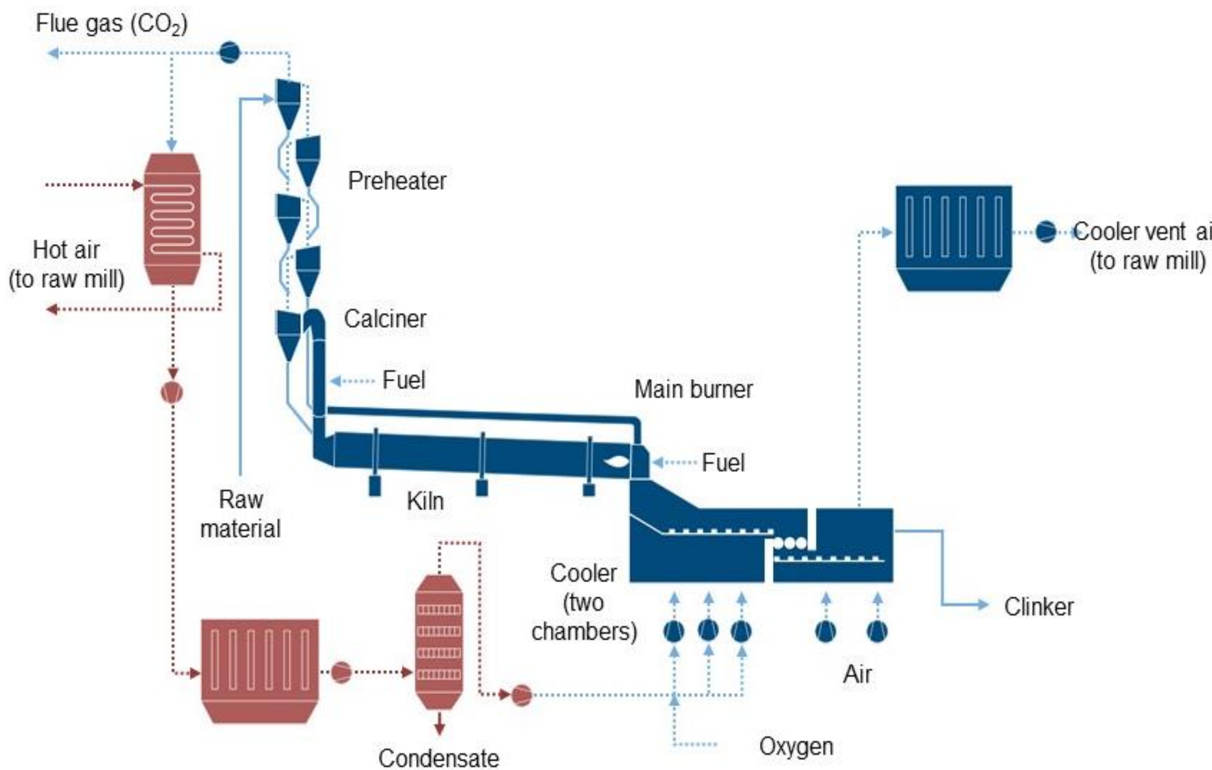
CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

TITAN

# AC²OCem Project Objectives

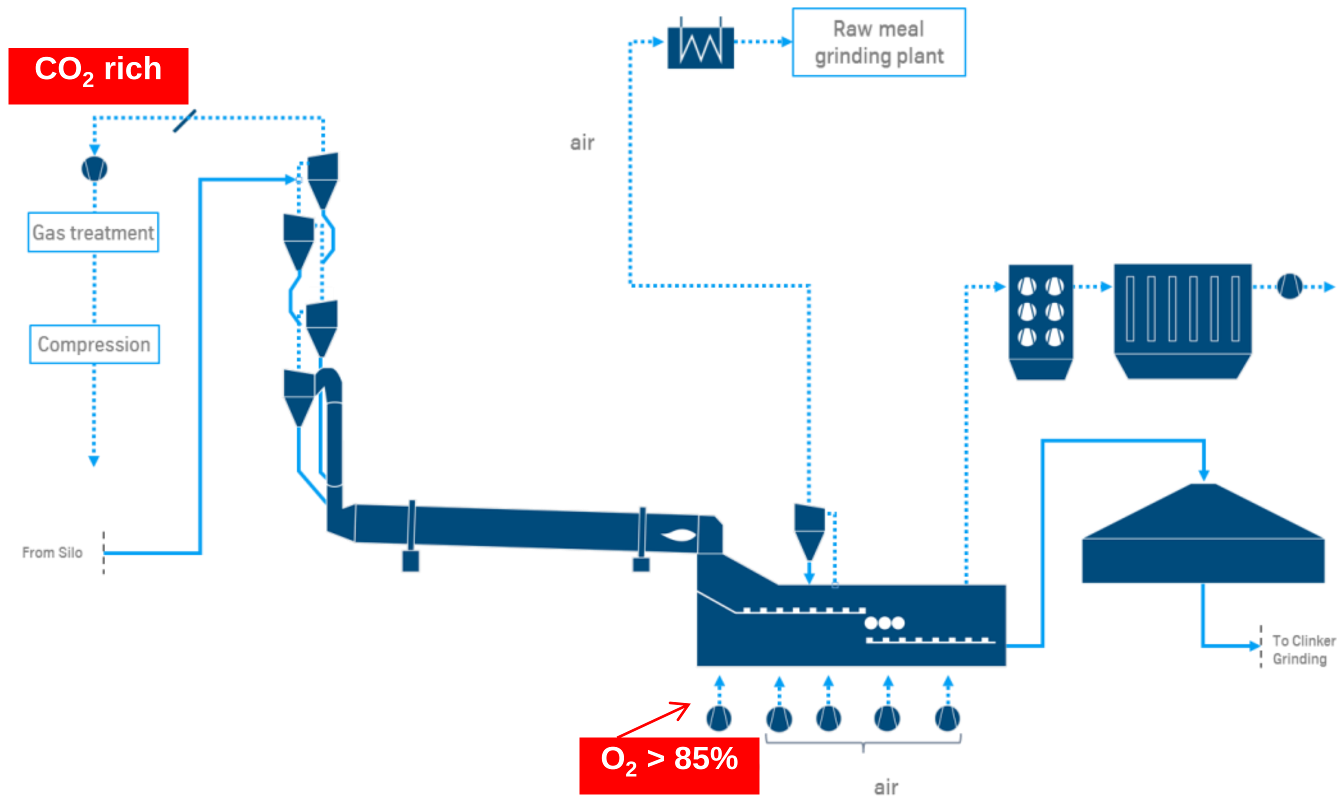
- Optimization of the oxyfuel cement process with the ultimate goal of **lowering the $CO_2$ avoidance cost**
- Advancing the 1st & 2nd generation oxyfuel technology for utilization **of up to 100% alternative fuels**, boosting $CO_2$ negative cement plants (**Bio-CCS**).
- **Retrofitability and Techno-economic analysis** of two selected demo oxyfuel plants in the frame of the ECRA CCS project, supporting transfer from TRL 6 to TRL 8
- **Developing and Testing a novel oxyfuel concept**, promoting this technology to the 2nd generation for new-build cement plants without flue gas recycle (up to TRL 6)
- Experimental and analytical investigations of the **2nd generation oxyfuel technology**, associated with a high reduction potential of energy demand, **CAPEX and OPEX**
- **Life cycle assessments** the environmental sustainability aspects of oxyfuel cement plants through

# 1st generation oxyfuel cement plant



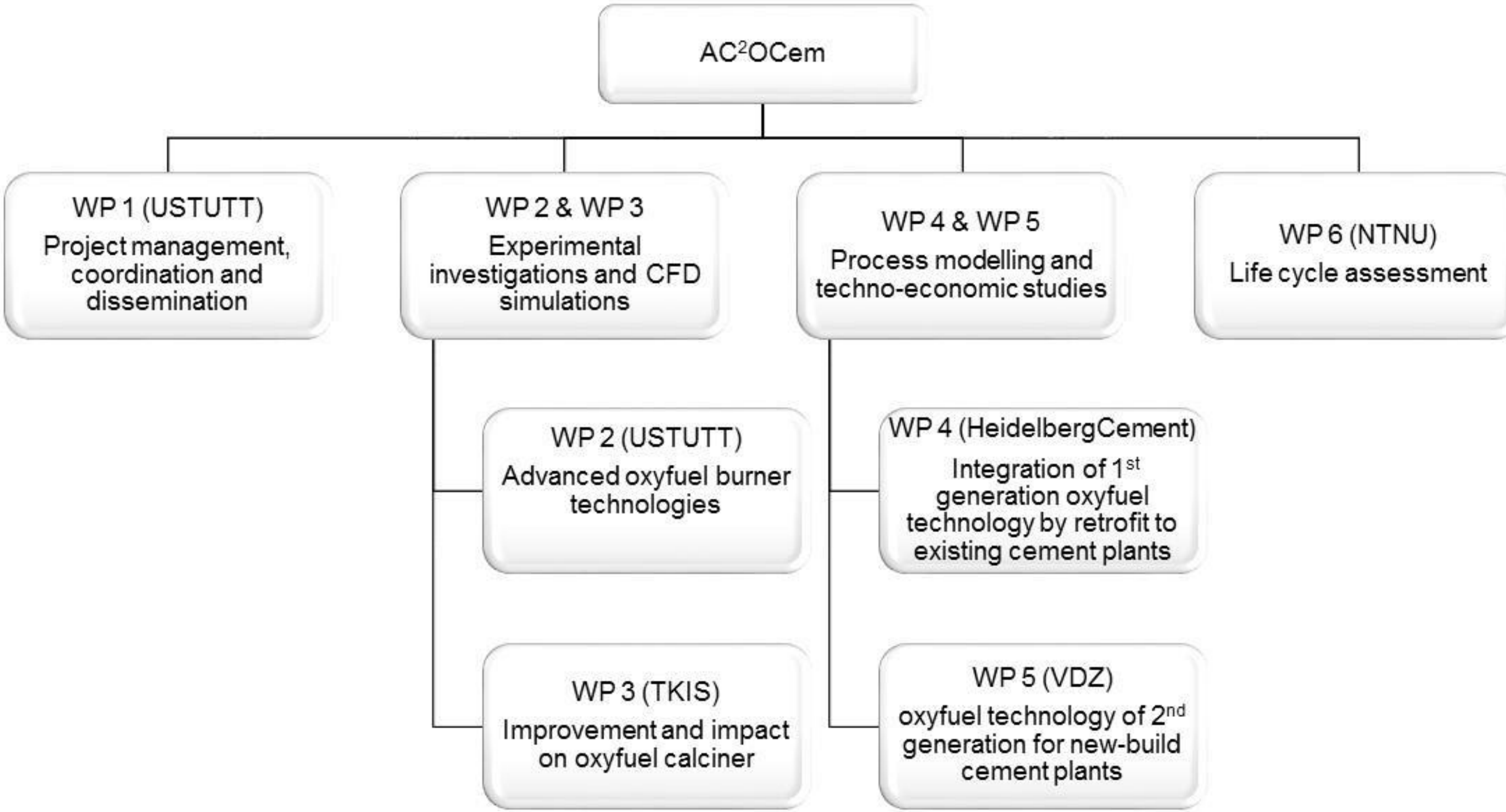

Schematic diagram of a 1st generation oxyfuel cement plant

# $2^{nd}$ generation oxyfuel cement plant




Schematic diagram of a $2^{nd}$ generation oxyfuel cement plant without flue gas recirculation circuit

# AC²OCem work package structure



# Work topics of WP 2: Advanced oxyfuel burner/ combustion technologies

**Task 2.1**: **Pilot-scale demonstration** tests of an advanced oxyfuel burner with selected oxygen enrichment for **up to 100% alternative** fuel Bio-CCS, 1$^{st}$ generation
(**USTUTT**, HeidelbergCement, LafargeHolcim, TKIS, TITAN)

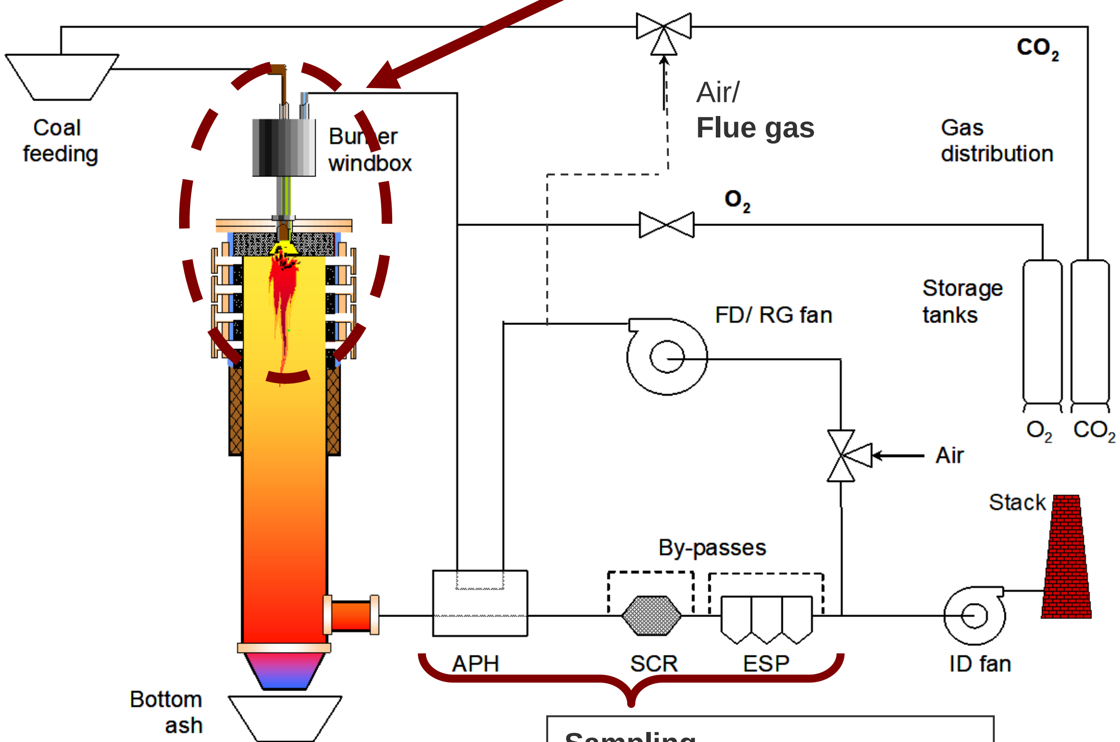
**Task 2.2**: **CFD simulations of the prototype burner for 1$^{st}$ generation** oxyfuel technology (**CERTH**, TKIS, USTUTT)

**Task 2.3**: **Pilot-scale demonstration** tests of prototype oxyfuel burner with the novel concept of up to 100 % oxygen and **without flue gas recycle** (**2$^{nd}$ generation oxyfuel technology**). (**USTUTT**, AL, HeidelbergCement, LafargeHolcim, SINTEF, TKIS, TITAN)

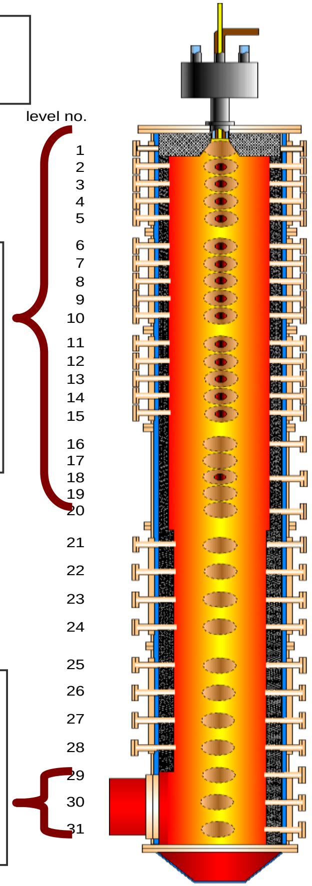
**Task 2.4**: **CFD simulations of the prototype burner for 2$^{nd}$ generation** oxyfuel technology (**SINTEF**, TKIS, USTUTT)

# WP 2: Air-Oxyfuel Test Facility at IFK (500kWth)

**Area of the major changes for the adaptation for the new burner design**




**Sampling**
- Ash, HCL, SO3




**Inflame Measurements**
- Gas emissions
- Gas temperature
- Heat Flux
- Radiation etc.

**Continuous gas emission measurements**

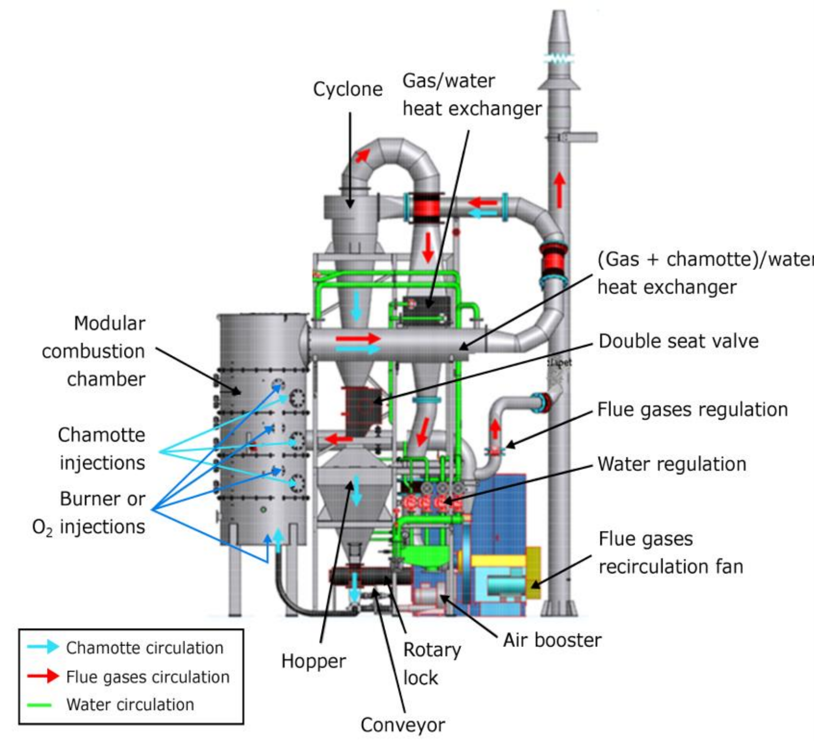
# Work topics of WP 3: Improvement and impact on oxyfuel calciner

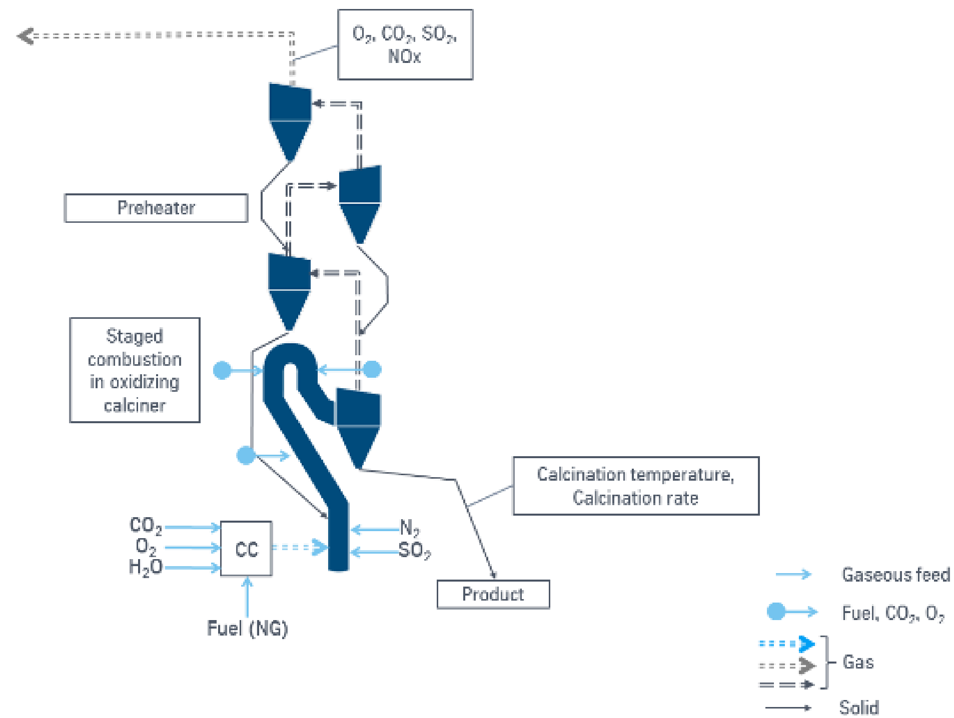
**Task 3.1**: Technical-scale **parametric study** to evaluate the impact of flue gas composition and impurities on calcination under oxyfuel conditions (**USTUTT**, TKIS, TITAN, VDZ)

**Task 3.2**: Demonstration of the **calcination test under oxyfuel atmosphere in a pilot-scale** calciner and pre-heater (**TKIS**, TITAN, USTUTT)

**Task 3.3**: Demonstration of up to **100 % alternative fuel combustion in a pilot-scale oxyfuel calciner** (**AL**, TITAN, USTUTT)

# WP 3: Schemes of pilot scale oxyfuel calciner facility from Air Liquide & TKIS




Schemes of pilot scale oxyfuel calciner facility from Air Liquide & TKIS

# Work topics of WP 4: Integration of 1st generation oxyfuel technology by retrofit to existing cement plants

**Task 4.1**: **Design considerations** for retrofitted oxyfuel cement plants (**VDZ**, CERTH, HeidelbergCement, LafargeHolcim, SINTEF, TKIS, TITAN)

**Task 4.2**: **Process simulations** of different flue gas recirculation scenarios and fuel mixes in oxyfuel retrofitted cement plants (**VDZ**, CERTH, HeidelbergCement, LafargeHolcim, SINTEF...)

**Task 4.3**: Assessments of **flue gas impurities** and residual streams in the oxyfuel retrofitted cement plant (**CERTH**, LafargeHolcim, TKIS, USTUTT, VDZ)

**Task 4.4**: Process simulations of the **influence of moisture** content in the raw material on process design and waste heat recovery (**VDZ**, HeidelbergCement, LafargeHolcim, SINTEF)

**Task 4.5**: Detection and control of **air ingress** for plant optimization (**HeidelbergCement**, LafargeHolcim, SINTEF, TKIS, TITAN, VDZ)

**Task 4.6**: **Techno-economic evaluation** of a retrofitted oxyfuel cement plant (**SINTEF**, AL, CERTH, HeidelbergCement, LafargeHolcim, TKIS, TITAN, TOTAL, VDZ)

# Work topics of WP 5: Oxyfuel technology of 2nd generation for new-build cement plants

**Task 5.1**: **Design considerations and process simulations** for new-build oxyfuel cement plants (**TKIS**, AL, HeidelbergCement, LafargeHolcim, SINTEF, TITAN, VDZ)

**Task 5.2**: Evaluation of the **impact of scale** in new-build oxyfuel cement plants (**VDZ**, HeidelbergCement, LafargeHolcim, SINTEF, TKIS, TITAN)

**Task 5.3**: Evaluation of **techno-economic feasibility** of new-build 2nd generation oxyfuel cement plants (**SINTEF**, AL, HeidelbergCement, LafargeHolcim, TKIS, TITAN, VDZ)

# Work topics of WP 6: Life cycle assessment (LCA)

**Task 6.1**: Gathering and **synthesis of primary data** (**NTNU**, HeidelbergCement, LafargeHolcim, SINTEF, TKIS, USTUTT, VDZ)

**Task 6.2**: **Life cycle assessment of 1$^{st}$ generation and new-build 2$^{nd}$ generation** oxyfuel cement plants (**NTNU**, HeidelbergCement, LafargeHolcim, Titan, SINTEF, TKIS, USTUTT, VDZ, CERTH)

**Task 6.3**: **Quantification** of the contributions in terms **of net potential for carbon capture and storage** of these technological solutions. (**NTNU**, VDZ)

# AC²OCem Project Gantt Chart 1

| WP / Task | Work package/task name | Lead Partner | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Months | | | | | | | | | | | | |
| **WP 1** | **Project management, coord., & dissemination** | **USTUTT** | | | | | | | | | | | | |
| 1.1 | Project Management, coord. & communication | USTUTT | M1.2 | D1.1 | | D1.2 | | | | | | | M1.3 | |
| 1.2 | Dissemination and exploitation of project results | USTUTT | | | | | | | | | | | | |
| 1.3 | Increasing public awareness of CCUS in industry | USTUTT | | | | | | | | | | | | |
| **WP 2** | **Advanced oxyfuel burner technology** | **USTUTT** | | | | | | | | | | | | |
| 2.1 | Pilot-S. Tests with selected O2 % for alt. fuel co-combustion (1st gen.) | USTUTT | | | | M2.1 | | | M2.2 | M2.3 | | M2.4 | | |
| 2.2 | CFD simulations of the prototype burner 1st gen. | CERTH | | | | | | | | | | | | |
| 2.3 | Pilot-S. Tests with up to 100% O2 without flue gas recycle (2nd gen.) | USTUTT | | | | | | | | | | | | |
| 2.4 | CFD simulations of the prototype burner 2nd gen. | SINTEF | | | | | | | | | | | | |
| **WP 3** | **Improvement and impact on oxyfuel calciner** | **TKIS** | | | | | | | | | | | | |
| 3.1 | Tech.-S. evaluation of flue gas comp. on calcination under oxyfuel cond. | USTUTT | | | M3.1 | | | | | M3.2 | | | | |
| 3.2 | Pilot-S. demo of 3.1 in calciner and pre-heater | TKIS | | | | | | | | | | | | |
| 3.3 | Demo. of up to 100 % alt. fuel combustion in a pilot-S. oxyfuel calciner | AL | | | | | | | | | | | M3.3 | |
| **WP 4** | **Integration of 1st gen. Oxyfuel tech. By retrofit to existing cement plant** | **HeidelbergCement** | | | | | | | | | | | | |
| 4.1 | Design considerations for retrofitted oxyfuel cement plants | VDZ | | M4.1 | | M4.2 | | | | | M4.4 | | M4.5 | D4.1 |
| 4.2 | Process simulations of diff. flue gas recirc. scenarios and fuel mixes in oxyfuel retrofitted cement plants | VDZ | | | | | | | | | | | | |
| 4.3 | Assessments of flue gas impurities and residual streams in the oxyfuel retrofitted cement pla | | | | | | | | | | | | | |
| 4.4 | Process simulations of the influence of moisture content in the raw material on process design and heat recovery | VDZ | | | | | | | | | | | | |
| 4.5 | Detection and control of air ingress for plant optimization | HeidelbergCement | | | | | | | | | | | | |
| 4.6 | Techno-economic evaluation of a retrofitted oxyfuel cement plant | SINTEF | | | | | | | | | | | | |
| **WP 5** | **Oxyfuel technology of 2nd generation for newbuild cement plants** | **VDZ** | | | | | | | | | | | | |
| 5.1 | Design considerations and process simulations for new-build oxyfuel cement plants | TKIS | | | | | | | | | | | | |
| 5.2 | Evaluation of the impact of scale in new-build oxyfuel cement plants | VDZ | | | | | | | | | | | | |
| 5.3 | Evaluation of techno-economic feasibility of new-build 2nd generation oxyfuel cement plants | SINTEF | | | | | | | | | | | | |
| **WP 6** | **Life cycle assessment (LCA)** | **NTNU** | | | | | | | | | | | | |
| 6.1 | Gathering and synthesis of primary data | | | | | | | | | | | | | |
| 6.2 | Life cycle assessment of retrofitted 1st generation and new-build 2nd generation oxyfuel cement plant | | | | | | | | | | | | | |
| 6.3 | Quantification of the contributions in terms of net potential for CCS of these technological solutions | NTNU | | | | | | | | | | | | |

M1.2 Kick-off meeting and template for deliverables distribution

D1.1 Project Website publicly available

M2.1 SRF characterization tests started

M3.1 Calcination Facility adaptations started

M2.2 Commissioning of 1st generation oxyfuel burner and facility

M4.1 Process model build-up of cement production process, heat integration and CPU started

# Acknowledgments

This project has received an ACT grant.

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University of Stuttgart
Germany

# Thank you!

**Dipl.-Ing. Jörg Maier**

e-mail joerg.maier@ifk.uni-stuttgart.de
phone +49 711 685-63396
fax +49 711 685-63491

University of Stuttgart
Institute of Combustion and Power Plant Technology
Pfaffenwaldring 23 • 70569 Stuttgart • Germany

ifk