ANICA

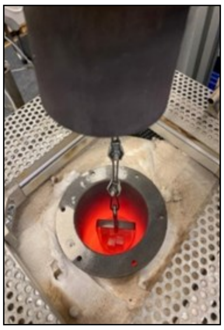
Advanced Indirectly Heated Carbonate Looping Process

Integrating the indirectly heated carbonate lopping process into the cement and lime industry for a sustainable CO_2-free production through CO_2 capture.

NEWSLETTER V - JULY, 2022

What will you find here?

Within the first pilot test, capture efficiencies of over 80% in the carbonator were achieved. Within the process model development, designs were established and key optimization parameters where identified. Arrangements and materials for heat pipes are being investigated. More information inside.



An exciting interview with Anna Dinkova, process engineer from thyssenkrupp Industrial solutions AG. She headed several R&D projects for cement pyro-processing plants, focusing on new processes in the field of heat recovery, emission reduction, and optimization of preheater cyclones and entrained flow calciner.

More than ten publications were made within the ANICA project. Check out the list of the latest publications here.

Project Overview

ANICA is an ACT project focused on developing novel integration concepts of the state-of-the-art indirectly heated carbonate lopping (IHCaL) process in cement and lime production. The project aims at lowering the energy penalty and CO_2 avoidance costs for CO_2 capture from lime and cement plants. The project is bringing the IHCaL technology to a high level of technical maturity by carrying out long-term pilot tests in industry-relevant environments and deploying accurate 1D and 3D simulations.

What has been achieved so far?

Four concepts for the integration of the IHCaL process into existing lime plants in Hönnetal (Lhoist Group) and Thessaloniki (CaO Hellas) have been developed (see Newsletter III, page 3). The corresponding one-dimensional simulations were successfully carried out. The first results were published in a peer-reviewed journal (Greco-Coppi et.al., 2021). Further results were presented in the 11th Trondheim Carbon Capture & Storage Conference. VDZ assessed concepts for the high level integration of the IHCaL process into a BAT (Best available technology) - cement plant.

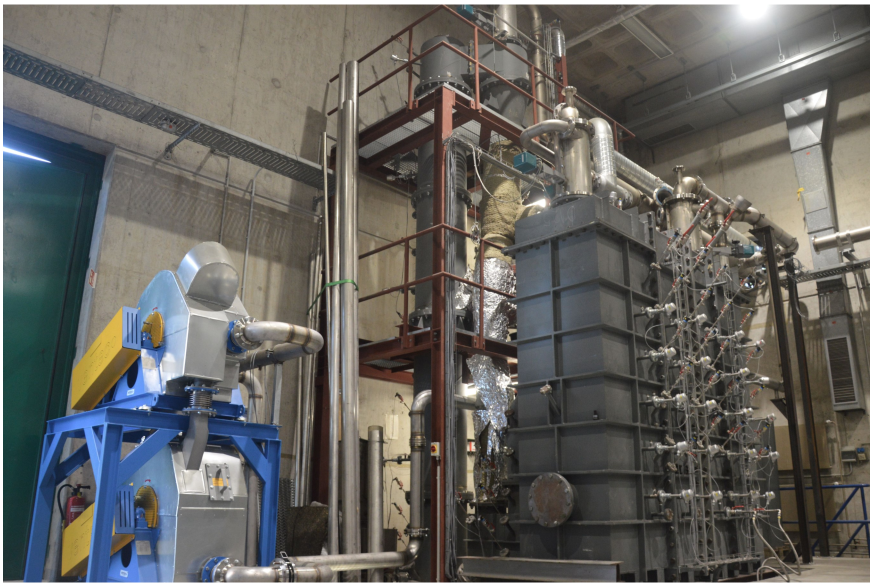


Figure 1: IHCaL pilot plant at TUDA

Regarding the experimental work, some results are already available and, with the in-series blowers and a new flue gas path, major changes at the pilot plant at TUDA (displayed in Figure 1) were implemented (see Newsletter IV, page 5). Long-term test-campaigns in the 300-kWth IHCaL testing facility at TUDA took place in January 2022. The first results are presented in this newsletter (page 4).

Furthermore, the first direct separation concepts for cement production are available, and the up-scaling works for an industrial-scale IHCaL facility are being performed, including technical and economical analysis as well as risk assessments with Monte Carlo simulations. Important results from the transient CFD model of the 300-kWth bubbling calciner, modelled following an Euler-Euler (TFM) approach, were produced. More information on the CFD simulations can be found on Newsletter IV, page 6.

Pilot Tests

The first pilot test within the ANICA-project has been finished in January this year, after 10 days of successful operation. The 300-kWth plant was recommissioned after more than 5-years without running. The external combustor, which is generating heat for the calcination, was connected with the carbonator, where flue gases are decarbonized.

Figure 2 shows the carbonator efficiency as a function of the average temperature in the carbonator. Within this first test campaign, capture efficiencies over 80 % were achieved. Various solid samples were taken during the first campaign, which are being analysed in terms of its consumption and potential to be used as raw material for limestone production. Some results were presented at the 24th International Conference on Fluidized Bed Conversion.

For the following campaigns, the heat for the calcination will be provided by combustion of solid feedstock such as waste-derived fuel, and efficiencies of over 90% will be pursued.

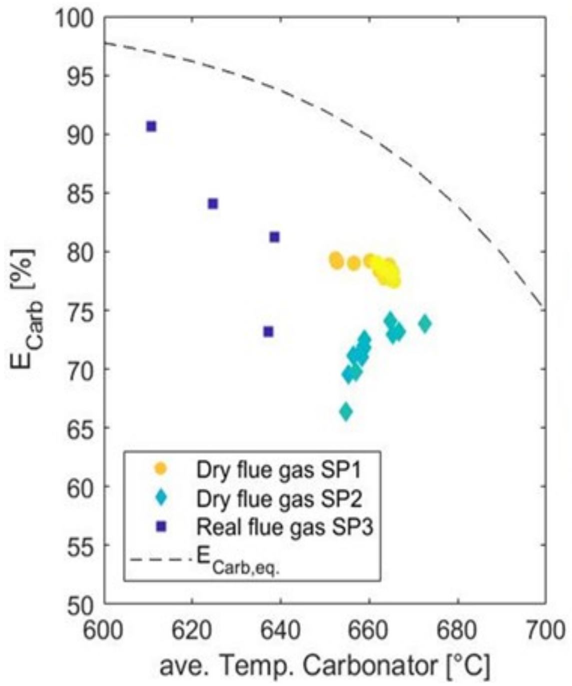


Figure 2: Carbonator efficiency over average temperature in the carboantor

PROCESS DEVELOPMENT

Preliminary concepts were developed for the integration of the IHCaL process into lime and clinker burning process. By implementing the process, priority was always given to high plant efficiency with maximum utilization of thermal energy.

PROCESS MODEL DEVELOPMENT

Preliminary concepts for the layout of the tail end IHCaL carbon capture demonstration plant based on fluidized beds were developed taking into account the equipment limits. An exemplary flow sheet is presented in Figure 3. The consortium is optimizing the gas temperature for the fans and the heat exchanger. To reduce costs and thermal efficiency the calculated heat and mass balances, the parameters with highest impact on the plant heat demand were identified. The main focus thereby is on the split preheating of the sorbent and the combustion air with the best available technique at the moment. In addition, the preliminary iterative routine for the dimensioning of the calciner and combustor was established.

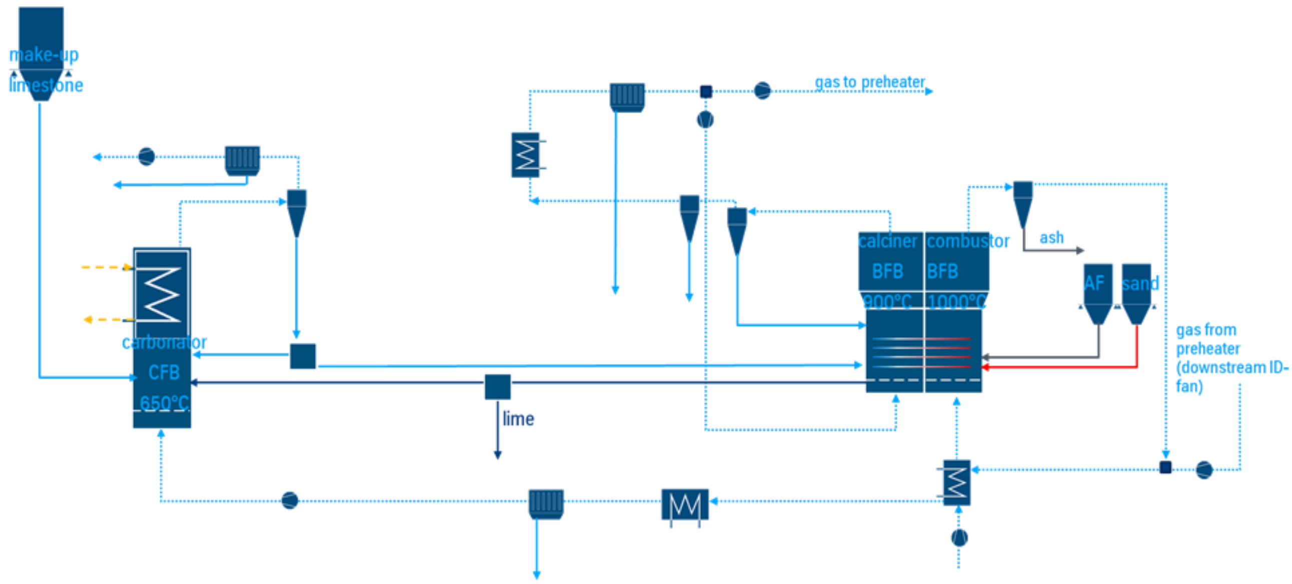


Figure 3: Preliminary flowsheet of the IHCaL demonstration plant based on fluidized beds for the cement industry

CLINKER BURNING PROCESS - ENVIRONMENTAL IMPACT

To understand the environmental impact (environmental benefit) of the clinker process with carbon capture, a cradle to gate life cycle assessment (LCA) was performed. Three plants were considered, the base case clinker plant and the clinker plant with two carbon capture integration options: the tail case and fully integration case. In the first iteration the plants are fuelled with hard coal, while the second considered each plant fuelled with solid recovered fuel (SRF).

The life cycle inventory (LCI) was constructed from the environmentally relevant flows identified in the mass and energy balances, and supplemented by published data. The main assumption is that excess heat is used to generate electricity for plant use with excess exported to the network. The plant receives an environmental credit for offsetting electricity generation elsewhere on the network. Table 1 shows parameters for each of the cases assessed while both tail cases have the greatest thermal input. The generation of electricity for network export is considerably high.

	Thermal input (MW)	CO_2 emission (t/h)	Utility power consumption (MW)	Electricity Import (MW)	Electricity Export (MW)
Hard Coal Base	105.10	106.49	18.41	18.41	0.00
SRF Base	104.19	102.42	18.41	18.41	0.00
Hard Coal Tail	425.40	22.68	56.14	0.00	61.09
SRF Tail	414.17	19.61	55.35	0.00	45.43
Hard Coal Integrated	236.40	10.60	46.85	0.00	0.00
SRF Integrated	194.97	9.00	46.85	2.53	0.00

Table 1: Technical parameters of clinker plant assessment

Figure 4 shows the single score LCA results. Both carbon capture integrations have a lower environmental impact than the base case clinker plant. For the hard coal case, the single scores are similar, and so other assessments, such as economic analysis should be used in conjunction with the LCA for decision making purposes. The assessment presented here indicates that switching from hard coal to SRF could further reduce the environmental impact of clinker production.

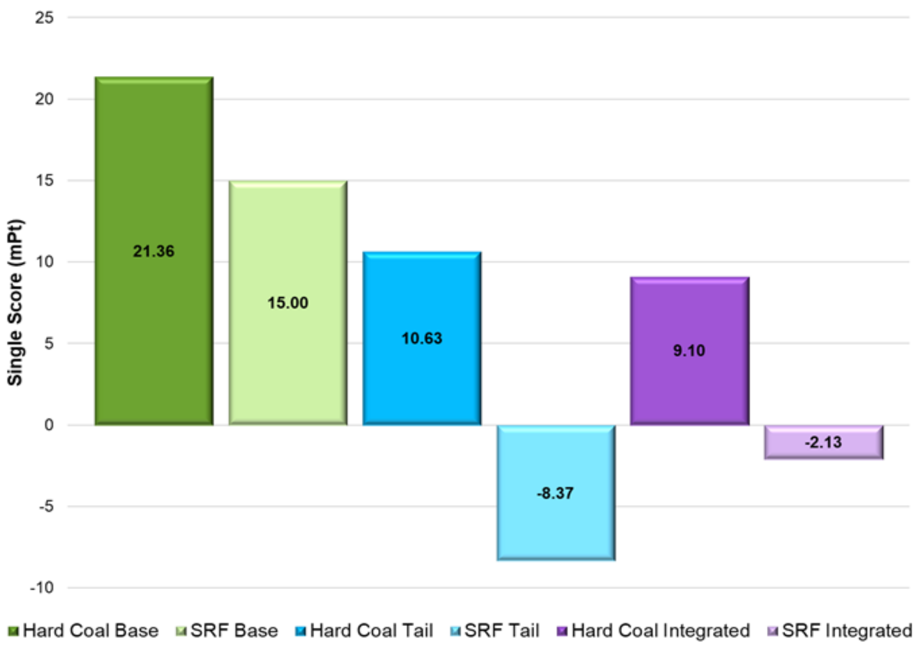


Figure 4: Single Score Result - Clinker Plant – 1kg Clinker Produced - ReCiPe Endpoint

REACTOR DEVELOPMENT

HEAT PIPE ARRANGEMENT

One of the main tasks of the ANICA-project is to increase the efficiency of the heat pipes heat exchanger and, thus reduce the total heat demand of the process. FAU is investigating the effect of the heat pipe arrangement on the heat transfer. For this purpose, plexiglass models were designed with two different pipe arrangements (aligned and staggered) in order to determine the corresponding heat transfer coefficients (see Figure 5). Experiments with these models will be carried out in the following months.

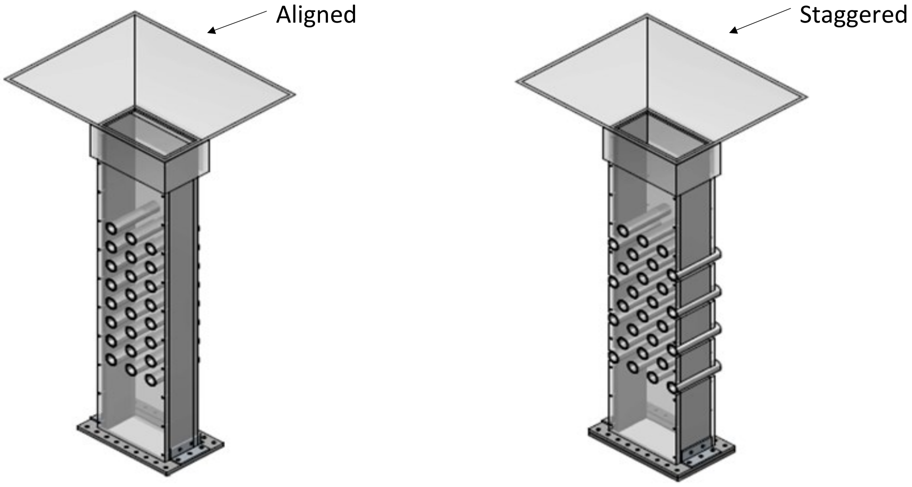


Figure 5: Two CAD images of the plexiglass fluidised beds with aligned (left) and staggered (right) tube arrangement.

DEVELOPMENT OF IMPROVED HEATPIPES

The FAU improved the design of the heat pipes to increase the heat flow. Furthermore, the perfomance limit was measured with an existing test rig. It turned out that the heat pipes in the 300-kWth pilot plant are only limited by the external heat transfer, i.e. from the fluidised bed into the pipes. This is due to the small area of the heat pipe of 0.1 m² in each fluidised bed, and the small temperature difference of 50-100 °C between the fluidised beds. The performance was improved and the thermal resistance was reduced to lower plant costs.

In addition, FAU explored the multiple start-up and shutdown behaviour of the steels (Figure 6).

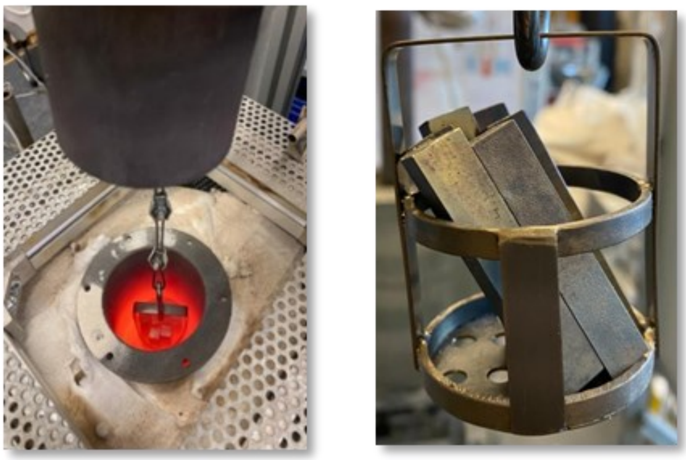


Figure 6: Experiment to investigate the multiple start-up and shutdown behaviour of the three different materials

The danger during the heat-up process is the formation of a sigma-phase embrittlement in the temperature range of 600- 900°C. However, at high temperatures >900°C the sigma-phase dissolves. Experiments were carried out with the three different materials used in the pilot plant (1.4835, 1.4841, 1.4876H) and the sigma-phase was indirectly inferred by means of the Charpy impact test. The results are shown in Figure 7. The material 1.4835 has the largest decrease in impact energy in the experiments 1 and 2. For all materials , the impact energy can be increased by heating up to 1050°C.

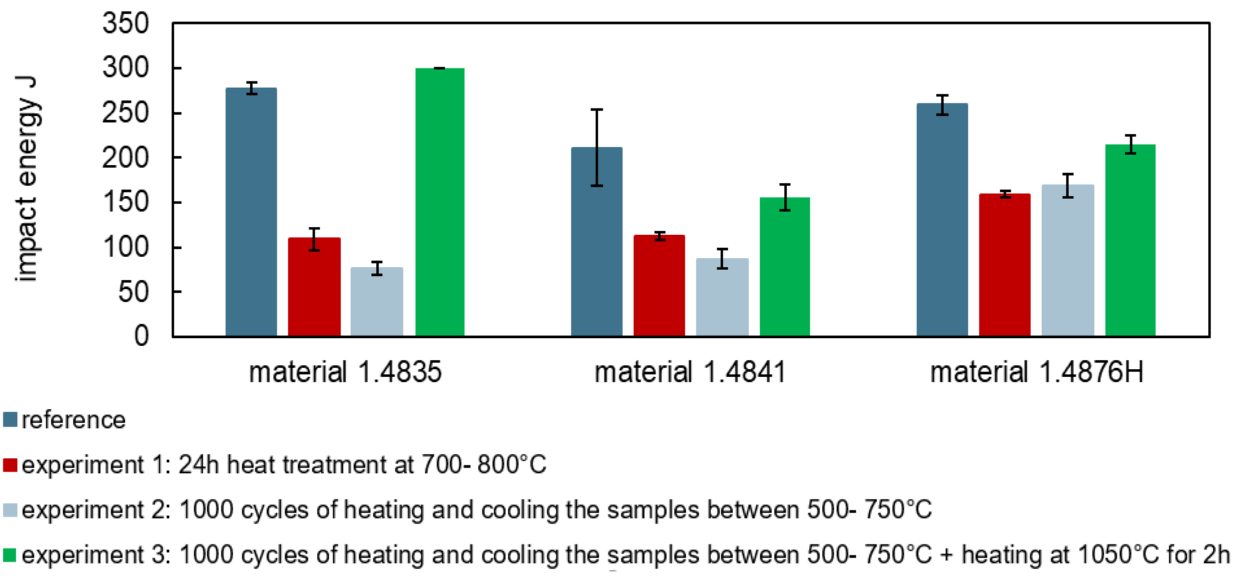


Figure 7: Results of the Charpy impact test of the three different materials used in the ANICA project (1.4835, 1.4841, 1.4876H)

THE VIEW FROM THE INDUSTRY

PLANT TECHNOLOGY SEGMENT OF THYSSENKRUPP

The Plant Technology segment of thyssenkrupp is a leading partner for the engineering, construction, and service of industrial plants and systems. Based on more than 200 years of experience, we supply tailored, turnkey plants and components for customers in the chemical, fertilizer, cement, and steel industries.

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In order to develop innovative concepts for the cement sector, especially in the sub-areas of raw material processing, clinker and cement production, and the sequestration and further use of CO_2, process and plant engineering knowledge is systematically combined to offer an overall economically optimal solutions. thyssenkrupp Industrial Solutions is committed to the concept of sustainability in its activities, especially with regard to resource conservation, avoidance of greenhouse gases and energy-efficient processes.

The Interview

What is thyssenkrupp Polysius? Can you tell us about its Mission?

The business unit Polysius of thyssenkrupp, with subsidiary companies on all 5 continents and around 3.800 employees all around the world, is one of the few full-range suppliers for the cement industry – from individual machines, all the way up to complete plants. In accordance with customer-specific requirements, we develop innovative machinery, technologies and processes to create intelligent production lines.

Today, one of the key challenges of the cement industry is reducing carbon emissions in the cement manufacturing process. A significant part of the CO_2 emissions is raw material-related and therefore cannot be completely eliminated with conventional optimization measures, such as the use of alternative fuels or the use of cement substitutes. Therefore, the cement division Polysius has agreed several years ago on the #grey2green strategy. In addition to avoiding fossil fuels, this strategy includes reducing emissions, using cement substitutes, increasing efficiency through the use of smart digital applications, and research into new, high-performance binders. With the green polysius® cement plant solutions, thyssenkrupp offers customers a more sustainable cement production, which also meets their requirements when it comes to economic efficiency and plant productivity.

OUR INTERVIEWEE: ANNA DINKOVA

Anna Dinkova is a diplom (master) process engineer at thyssenkrupp Industrial Solutions, business unit Polysius. She headed several R&D projects for cement pyro-processing plants focusing on new processes in the field of heat recovery, emission reduction and optimization of preheater cyclones and entrained flow calciner.

How does the ANICA Project align with the company's vision?

Reducing CO_2 emissions in cement production is one of the most important challenges the industry is facing today. As part of our #grey2green journey we are developing technologies and solutions for sustainable cement production without losing sight of plant profitability and productivity. The results of ANICA will provide thyssenkrupp further insights into the IHCaL process and its technological implementation to reduce carbon dioxide emissions in the production of cement clinker. Considerations with regard to the economic efficiency and reliability of the process will allow us to compare with other technologies for CO_2 separation. Thus, we will be able to market the best solution for the specific requirements of our partners.

Why is it important that thyssenkrupp Industrial Solutions is involved in the ANICA Project? What role does it play in the consortium?

At thyssenkrupp we are convinced that CO_2-neutral cement production is fundamentally possible. The cement industry is engaged in several decarbonisation strategies. Some of them are technically feasible but need further development to become ALSO economically feasible. This can be achieved only through interdisciplinary teams from scientific, operational and plant engineering experts. Our plants and machines use state-of-the-art production processes to optimize resource utilization, minimize environmental impact, and deliver maximum performance and efficiency. Through our engineering expertise in cement plant design we contribute to the development of the IHCaL integration in the cement process and the reactor design of the carbonator and the calciner.

What appealed to you personally in the ANICA project, sparking the interest to get involved in it?

The cement industry alone accounts for seven percent of global CO_2 emissions, and is, therefore, particularly challenged to protect the climate with environmentally friendly technologies. We are experiencing one of the most exciting industrial transformations of our generation, and I am happy to be involved in the development of the technological solutions.

What is your role in the project and what expertise do you bring to the consortium?

Together with our partners from Dyckerhoff AG, CERTH,TU Darmstadt and University of Erlangen, the thyssenkrupp Industrial Solutions multidisciplinary team delivers the design of an IHCaL demonstration plant, and provides a cost estimation for it. I am leading the development of a fluidized bed demonstration plant.

Do you have any final words for our readers?

From our perspective as plant engineers, new technologies need several years of development. Thorough testing is required before the application in the complex and high-volume cement production process. There is a need to act now if we want to see the required change in the years to come.

LATEST PUBLICATIONS

Several publications were made during the ANICA project. The latest are listed here for more detailed information and description of the project progresses. More publications can be found in Newsletter IV, page 2.

M. Greco-Coppi et al., *Efficient CO2 Capture from Lime Production by an Indirectly Heated Carbonate Looping Process.* International Journal of Greenhouse Gas Control 112 (2021) 103430.
DOI: https://doi.org/10.1016/j.ijggc.2021.103430

C. Hofmann et al., *Adaption of a 300 kWth Pilot Plant for Testing the Indirectly Heated Carbonate Looping Process for CO2 Capture from Lime and Cement Industry*, 13th European Conference on Industrial Furnaces and Boilers (2022)

G. Kanellis et al., *Development and numerical investigation of a DDPM-KTGF model for modeling flow hydrodynamics and heat transfer phenomena in a bubbling calciner reactor*, 24th International Conference on Fluidized Bed Conversion (2022)

G. Kanellis et al., *CFD modelling of an indirectly heated calciner reactor, utilized for CO2 capture, in an Eulerian framework*, 24th International Conference on Fluidized Bed Conversion (2022)

C. Hofmann et al., *Operation of a 300 kWth Indirectly Heated Carbonate Looping Pilot Plant for CO2 Capture form Lime Industry*, 24th International Conference on Fluidized Bed Conversion (2022)

M. Greco-Coppi et al., *Negative CO2 Emissions in the Lime Production Using an Indirectly Heated Carbonate Looping Process*, 2nd International Conference on Negative CO2 Emissions (2022)

The Consortium

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