CLEAN clinKER production by Calcium looping process

Berichterstattung

Projektinformationen

CLEANKER

ID Finanzhilfevereinbarung: 764816

Projektwebsite

DOI
10.3030/764816

Projekt abgeschlossen

EK-Unterschriftsdatum
28 August 2017

Startdatum
1 Oktober 2017

Enddatum
31 März 2023

Finanziert unter
SOCIETAL CHALLENGES - Secure, clean and efficient energy

Gesamtkosten
€ 9 237 851,25

EU-Beitrag
€ 8 972 201,25

Koordiniert durch
LABORATORIO ENERGIA AMBIENTE PIACENZA
Italy

Periodic Reporting for period 3 - CLEANKER (CLEAN clinKER production by Calcium looping process)

Berichtszeitraum: 2020-04-01 bis 2023-03-31

Zusammenfassung vom Kontext und den Gesamtzielen des Projekts

The cement industry is responsible for a significant portion of global anthropogenic CO2 emissions, with around 27% from industrial sources and 6-7% globally. Most of CO2 emission in cement production (~60%) is unavoidable, occurring during the calcination of limestone. The remaining ~40%

comes from fuel combustion and electricity generation. Carbon Capture and Storage systems are needed for the production of carbon neutral clinker. Calcium Looping (CaL) is a regenerative process that captures CO2 by using calcium oxide-based sorbents to adsorb it at high temperatures. The CaL process has two steps: limestone calcination in oxy-fired calciner and separation of CO2 in the rotary kiln exhaust gases using carbonator reactor. The CaL process has a CO2 capture efficiency target of >90% and high-energy efficiency, with low overall energy consumption through integration with raw meal preheating and heat recovery. The project involves designing, constructing, and operating an integrated CaL demonstration system based on entrained-flow (EF) CaL reactors at the BUZZI kiln of the Vernasca cement plant in Italy. Other activities include screening different raw meals for CO2 sorbent properties, process modeling, scale-up studies, economic analyses, life cycle assessment, CO2 transport, storage, and utilization studies, demonstration of the complete value chain, and exploitation study for the demonstration of the technology.

Arbeit, die ab Beginn des Projekts bis zum Ende des durch den Bericht erfassten Berichtszeitraums geleistet wurde, und die wichtigsten bis dahin erzielten Ergebnisse

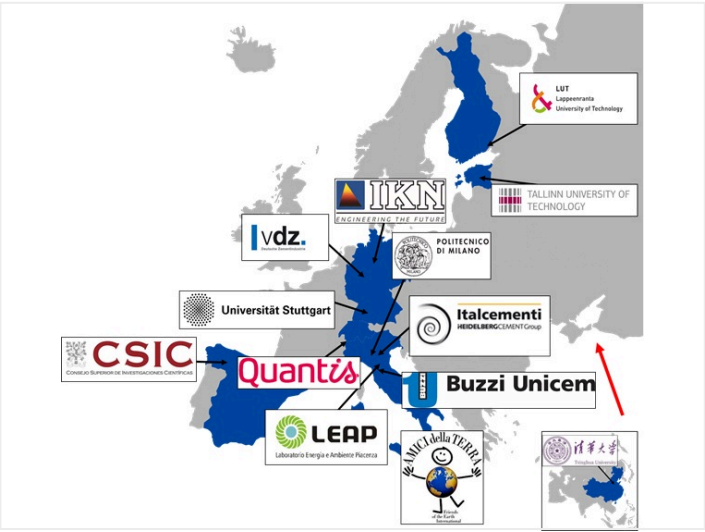
CLEANKER aimed to demonstrate the Integrated Calcium Looping (CaL) concept at TRL7 over a period of 5 years and 1/2. The project had three phases: during the first (2017-18), raw meal properties as CO2 sorbent were characterized, and the CaL pilot components were designed and constructed. In the central period (2019-20), the CaL pilot plant was erected and commissioned, while parallel activities were dedicated to evaluate CO2 storage options, prepare the CO2 mineralization tests and develop simulation and analytical tools. In the third and final period (2021-23), the experimental campaigns were executed, confirming the viability of both partial oxyfuel and integrated CaL technologies for CO2 capture in cement plants. The demonstration system, comprising the EF carbonator and oxyfuel calciner, was operated in Vernasca, Italy, capturing around 100 tons of CO2 over a duration of 200 h of CaL in oxyfuel mode testing and 270 h of raw meal feeding to the calciner across 5 short and 4 long tests.
Other CLEANKER activities included:
1) Experimental characterization of sorbent material: researchers at CSIC and USTUTT have developed a method for characterizing raw meals as CO2 sorbent in integrated CaL process, and have applied it to raw meals from Vernasca and other cement plants. The lab tests have revealed that belite formation in the calciner hinders the CO2 capture capacity of calcined raw meal, as CaO chemically bonded with SiO2 subtracts active sorbent from the calcined raw meal. The higher the level of aggregation of Ca and SiO2 grains in the raw meal, the higher the formation of belite, and the lower the CO2 sorption capacity of the calcined raw meal. Material sampled from the exit of the calciner and carbonator of the Vernasca pilot plant has also been characterized. The sorbent utilization factor in the pilot is about 50% of the maximum sorbent conversion. Overall, the data show that the samples from the pilot retain sufficient carbonation capacity for CaL process, comparable to what is predicted from the lab test procedure developed at CSIC and USTUTT
2) CLEANKER process scale-up and techno-economic-environmental analysis: process simulations have shown that a full-scale integrated CaL process leads to a significant increase in fuel consumption (up to +60-70%) and high capital costs, mainly due to the air separation unit, CO2

compression and purification unit, and heat recovery steam cycle (70% of total CAPEX). However, the heat from additional fuel combustion can be recovered at high temperature to self-produce low-carbon electricity, balancing the electric consumption for O2 production and CO2 compression. A new design for key components has been proposed for the full-scale plant to improve its overall performance. An economic analysis has estimated that a carbon tax of 35-60 €/t would make a CLEANKER plant competitive with an unabated cement plant (without considering CO2 transport and storage costs). Moreover, the use of alternative fuels with biogenic carbon content can lead to net negative emissions from an LCA balance. The carbon footprint of the integrated CaL system was estimated and compared to the footprint of other carbon capture processes, showing that the CLEANKER technology has the potential of reducing the climate impact of cement production by 75% (and over 100% if alternative fuels are used)
3) New and revised dimensional models (1D-3D) for the interconnected CaL reactors (EF calciner and carbonator) were developed exploiting the kinetics law obtained exploiting the lab and pilot analysis. The carbonation and calcination reaction rates of Vernasca raw meal is now included in the 1D and 3D routines, as well as the kinetics of belite formation
4) Design and commissioning of CO2 mineral trapping facility for mineralization tests in Vernasca: three 40 kg batches of Estonian burnt oil shale (BOS) were carbonated using Vernasca pilot plant CO2-rich gases, capturing 6-26 g CO2 per 1 kg BOS. Carbonated BOS was added to 2 m3 of concrete in BUZZI cement plant in Trino, Italy, showing no significant performance changes to concrete, proving feasibility of utilizing this material in an industrial end product while permanently storing CO2. The test stored around 4 kg CO2 per m3 of concrete, which can be increased using optimal apparatus solutions for carbonating fresh BOS
5) Methodology for modelling of the Baltic and Italian CCUS scenarios: Captured CO2 from cement plants needs to be stored geologically. Scenarios in Italy and the Baltic region have been assessed for CO2 transport and storage, with the Baltic CCUS scenario combining storage and mineralization to avoid 6.8 MtCO2/y from cement and power plants in the region
6) Several dissemination and communication actions have been carried out during the whole project duration, to enhance the CLEANKER knowledge sharing

Fortschritte, die über den aktuellen Stand der Technik hinausgehen und voraussichtliche potenzielle Auswirkungen (einschließlich der bis dato erzielten sozioökonomischen Auswirkungen und weiter gefassten gesellschaftlichen Auswirkungen des Projekts)

Thanks to CLEANKER, the integrated CaL technology has been successfully brought to TRL7 in cement industry testing the process in EF reactors and exploiting the potential of cement raw material as CO2-sorbent.
The project worked closely with the High-Temperature Solid Looping Cycles Network to promote further development and collaborations among partners.
The expected impact of CLEANKER project, was substantially achieved.
•Environmental and societal, through mitigation of climate change: the CLEANKER target of capturing of 90% of CO2 was demonstrated during the experimental campaigns

•Technical-scientific: new knowledge both at experimental and modelling levels was created and shared among the scientific community
•Social, through the increase of the public awareness on CCS and on sustainable cement production. For this purpose, different successful events have been organized, both with general public, local communities and local and regional administrations. The most important one was the opening event of the demonstrator, held in Vernasca in October 2020



consortium.jpg

cementeria.jpg

Letzte Aktualisierung: 24 Juli 2024

Permalink: https://cordis.europa.eu/project/id/764816/reporting/de