



# CEMCAP



## CEMCAP

### TECHNOLOGICAL ACHIEVEMENTS AND KEY CONCLUSIONS

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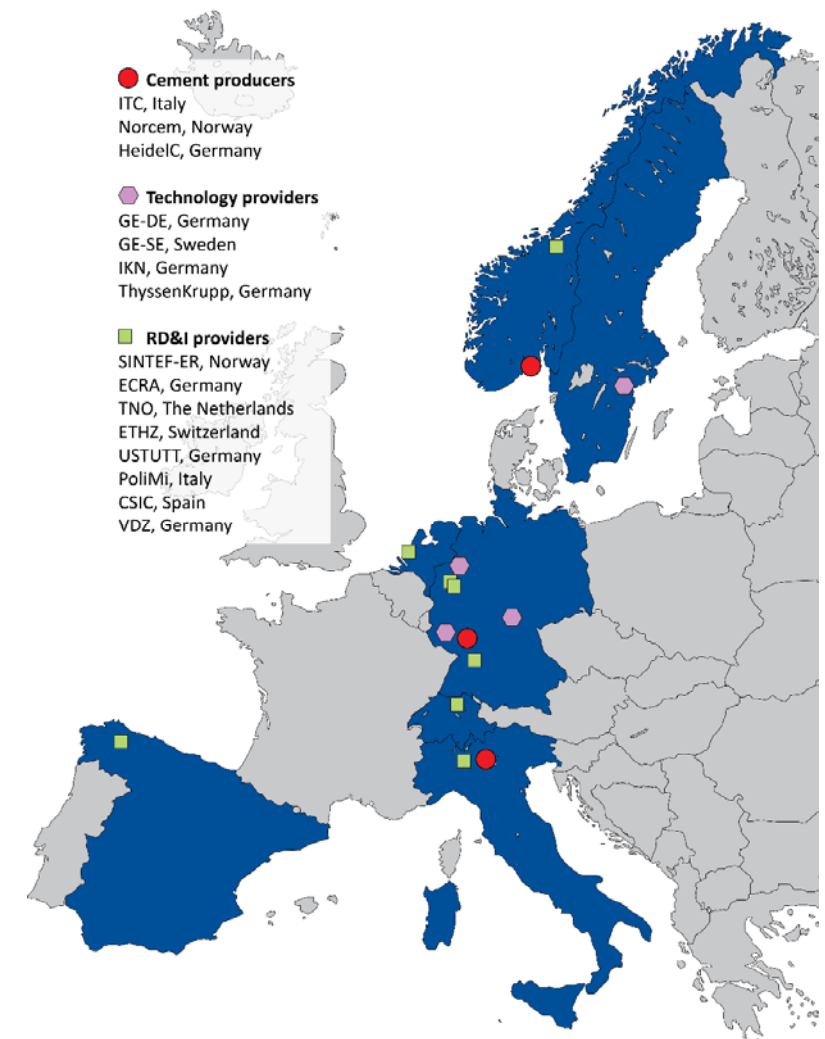
# About CEMCAP

Duration: May 2015-October 2018

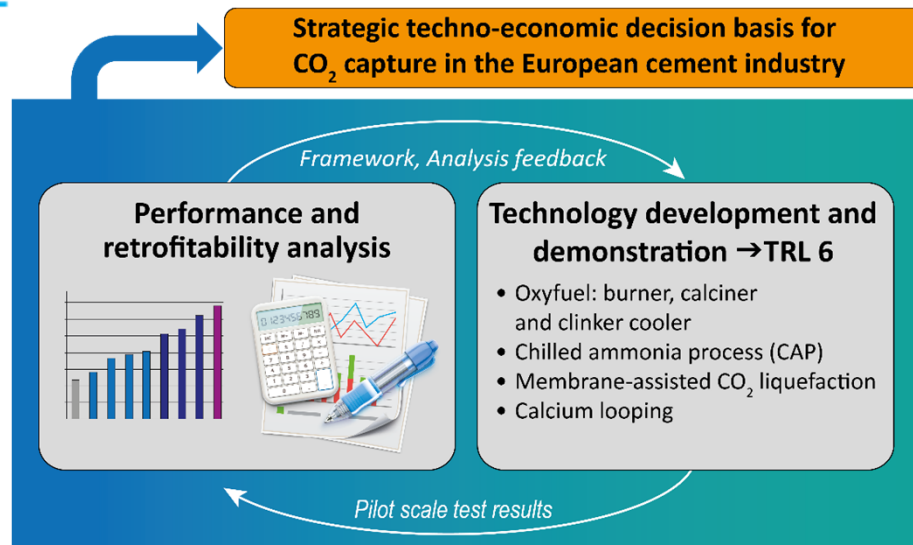
Budget: €10,030,120.75

EU contribution: €8,778,701.00

Main objective: *To prepare the ground for large-scale implementation of CO<sub>2</sub> capture in the European cement industry*



# A consistent project



- Tight connection analytical ↔ experimental work
- A common framework document established to ensure project consistency



**CEMCAP**

Grant Agreement Number:  
**641185**

Action acronym:  
**CEMCAP**

Action full title:  
**CO<sub>2</sub> capture from cement production**

Type of action:  
H2020-LCE-2014-2015/H2020-LCE-2014-1

Starting date of the action: 2015-05-01  
Duration: 42 months

**D3.2**  
**CEMCAP framework for comparative techno-economic analysis of CO<sub>2</sub> capture from cement plants**

*Revision 2*

Due delivery date: 2017-01-31  
Actual delivery date: 2017-05-11  
Revised version delivery date: 2018-02-12

Organisation name of lead participant for this deliverable:  
**SINTEF-ER**

Project co-funded by the European Commission within Horizon2020		
Dissemination Level		
PU	Public	x
CO	Confidential, only for members of the consortium (including the Commission Services)	

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# CO<sub>2</sub> capture technologies in CEMCAP

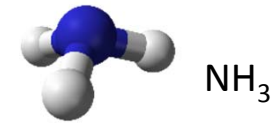
Capture technology	Oxyfuel	Chilled Ammonia Process	Membrane-Assisted Liquefaction	Calcium Looping	
				Tail-end	Integrated

The capture technologies are fundamentally different, with different strengths and challenges

Energy provision	Power	Steam and power	Power	Fuel and power
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CO<sub>2</sub> capture requires energy and costs money – CEMCAP did not change this fact but we have decreased the uncertainty about the numbers for the cement industry





- commodity chemical
- globally available
- chemically stable

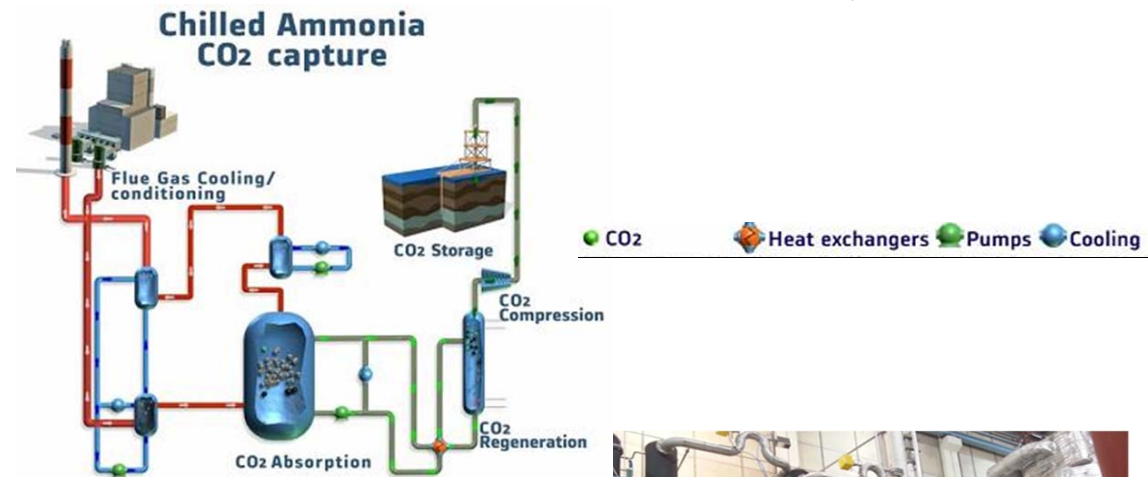
# Chilled Ammonia Process (CAP)

## • Principle

- Aqueous ammonia absorbs  $\text{CO}_2$  in absorption column
- Solution is regenerated through heating at pressure

## • Research:

- In pilot scale investigate process differences between cement and power
- Thermodynamic and kinetic model development
- Process optimization for cement application







- commodity chemical
- globally available
- chemically stable

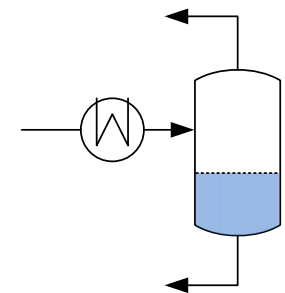
# CAP: achievements in CEMCAP

- Validated process models
- CAP exploits high  $\text{CO}_2$  concentrations for highly efficient capture
- Validated CAP functionality
  - All process units that are affected by new flue gas composition tested
  - CAP ready for on-site demonstration

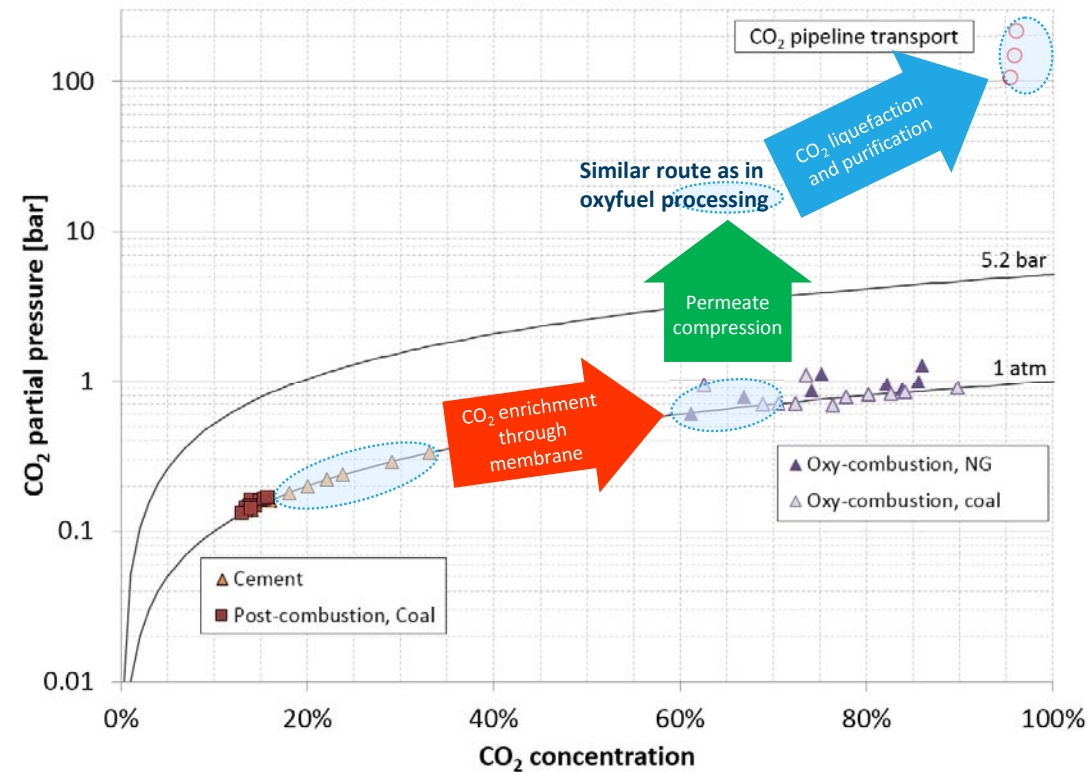


Product Validation Facility at the Mountaineer power plant, WV (50 MW<sub>th</sub>):8000 h in 2009-2011

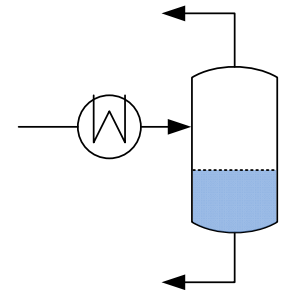
# Membrane-Assisted Liquefaction (MAL)



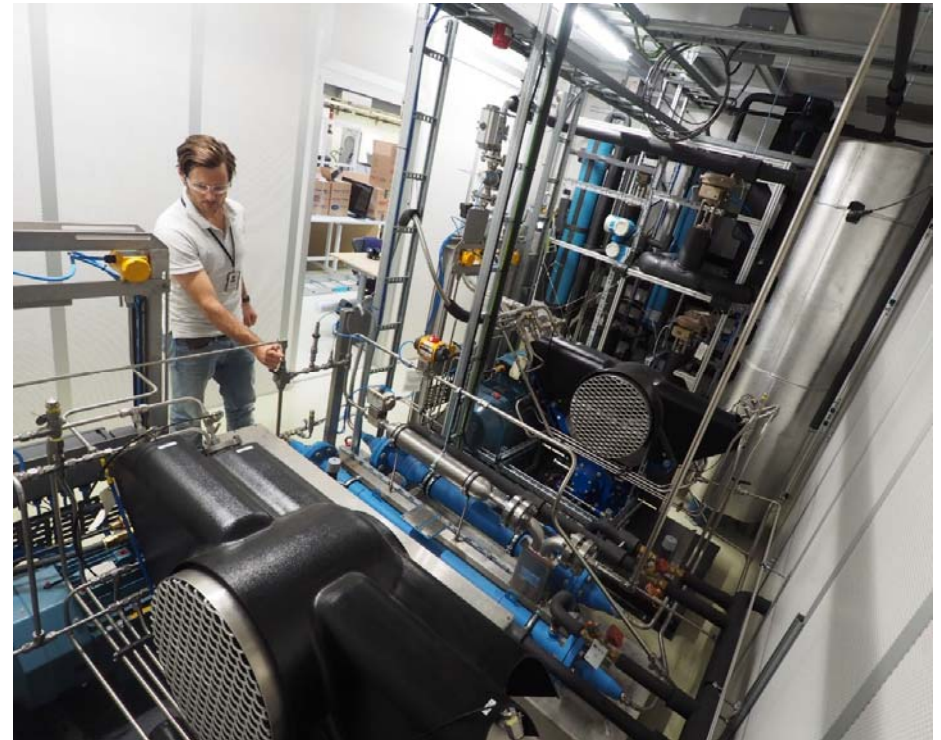
- Principle: Flue gas is CO<sub>2</sub>-enriched through membranes to "low-end oxyfuel" conditions. Thereafter compressed, cooled and condensed
- Research:
  - Membrane testing in lab
  - Development of MAL process schemes
  - Demonstration of CO<sub>2</sub> liquefaction on pilot scale



# MAL: achievements in CEMCAP



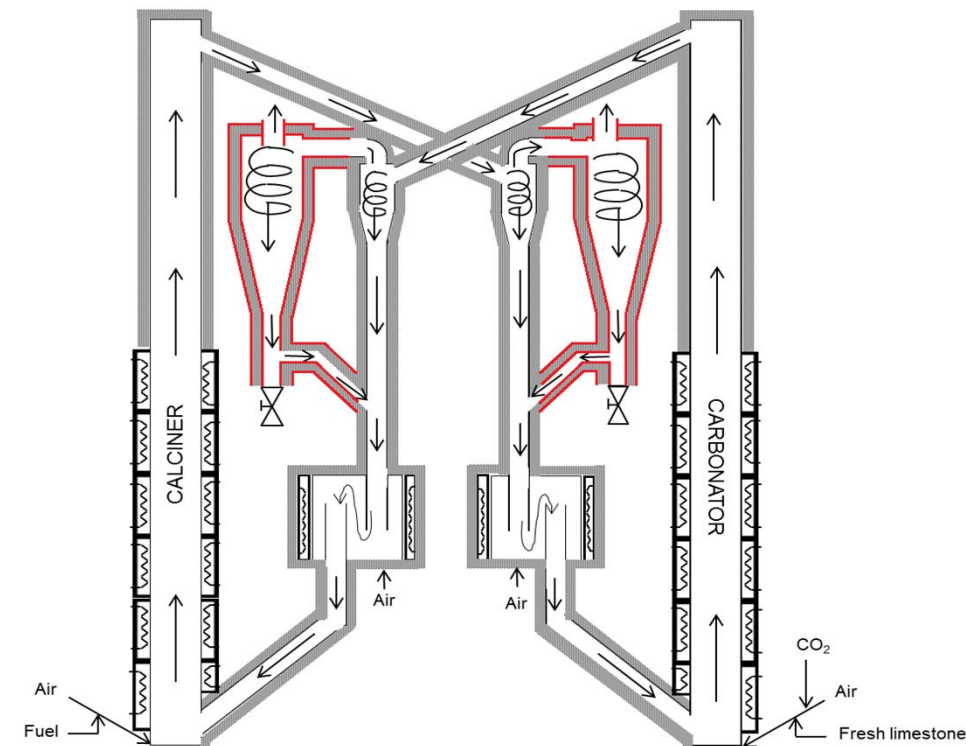
- Polymeric membranes
  - Tested selectivity and permeability of two membrane materials
  - CO<sub>2</sub>/N<sub>2</sub> selectivity sufficient: provides sufficient CO<sub>2</sub> concentration for efficient liquefaction
- Demonstrated operability of CO<sub>2</sub> liquefaction in 5-10 ton/day scale
  - Binary CO<sub>2</sub>/N<sub>2</sub> mixtures with CO<sub>2</sub> concentration relevant for MAL applications
  - Very high CO<sub>2</sub> product purity measured, up to 99.8 %





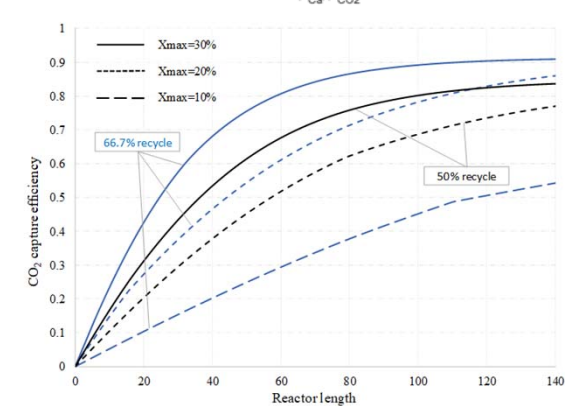
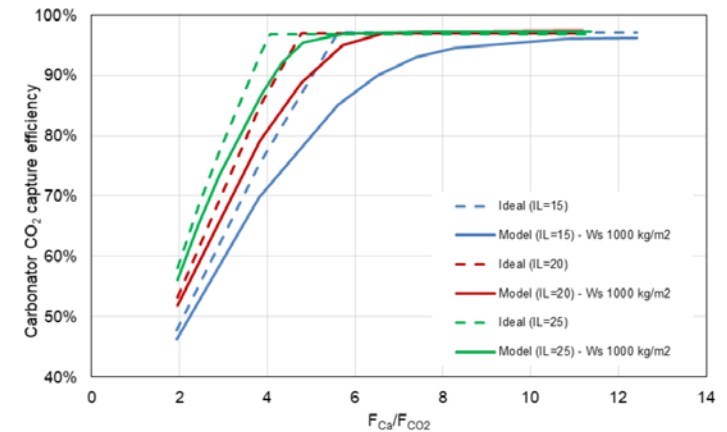
# Calcium looping Capture (CaL)

- Principle:  $\text{CO}_2$  is captured in a carbonator through the reaction of  $\text{CaO} \rightarrow \text{CaCO}_3$ , and released in a calciner through the opposite reactions. Requires heat.
- Research:
  - Two configurations investigated
  - Tail-end & Integrated entrained flow
  - Experimental investigation at two scales:  $30 \text{ kW}_{\text{th}}$  and  $200 \text{ kW}_{\text{th}}$



# Calcium Looping (CaL): Achievements in CEMCAP

- Two configurations investigated
  - Tail-end: most mature
  - Integrated entrained flow: more energy efficient
- High CO<sub>2</sub> capture rates (up til 98%) with tail-end CaL. Ready for on-site demo after CEMCAP
- Integrated entrained flow CaL spin-off: CLEANKER project (on-site demo)



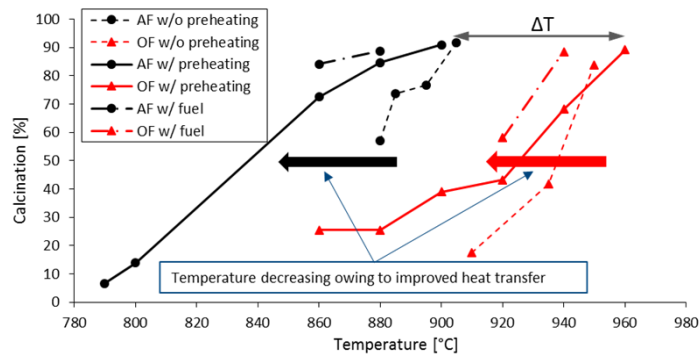
# Oxyfuel: Achievements in CEMCAP



0.00 0.10 0.21 0.31 0.42 0.52 0.63 0.70



Oxyfuel burner testing and simulations



Entrained flow oxyfuel calcination testing



Oxyfuel clinker cooler prototype testing

The existing ECRA/VDZ oxyfuel process model was adapted in accordance with the experimental results



# Oxyfuel: Achievements in CEMCAP





# The next steps for the CEMCAP technologies

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- Oxyfuel: ECRA CCS project plans for 2 demos at Colleferro (IT) and Retznei (AT)
- CAP: Pilot plant of 100,000 tCO<sub>2</sub>/year envisioned
  - GE has full EPC capacity
- MAL: needs on-site screening of different membranes at operating cement kiln.
  - Liquefaction needs to be tested/demonstrated with flue gas impurities
- Tail-end CaL: ready for on-site testing
- Entrained-flow CaL: Is being brought to on-site demo in the CLEANKER project



# Post-capture CO<sub>2</sub> management

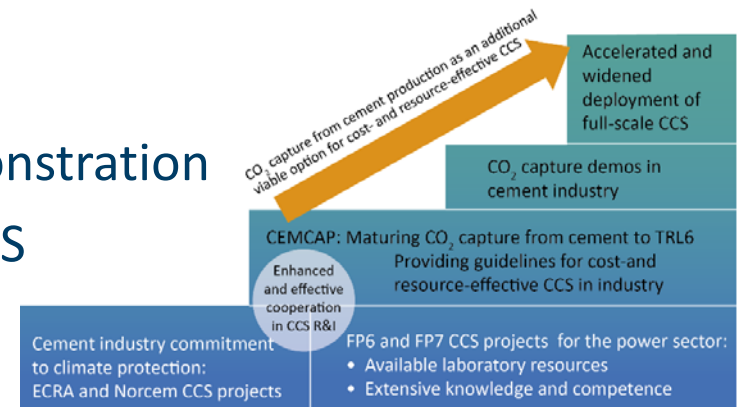
- Cement production is a potential carbon source in a fossil-free future
  - But CO<sub>2</sub> is a very stable molecule, its conversion processes are normally highly energy intensive
- 16 CO<sub>2</sub>-based products evaluated in CEMCAP
  - Current CO<sub>2</sub> utilization (CCU) routes have limited opportunity for climate change mitigation in the cement industry context
  - Likely < 10% of CO<sub>2</sub> from a cement plant can be used for CCU
  - Niche applications with positive CCUS business cases
- **“CCU” always needs “S”**: either market or raw material availability poses limitation on the amount of CO<sub>2</sub> that can be utilized.



Product	Market	Energy demand	Maturity	Price
CaCO <sub>3</sub> (GCC)				
CaCO <sub>3</sub> (PCC)				
Aggregates				
Carbonated concrete				
Methanol				
DME				
Methane				
Ethanol				
Isopropanol				
Biodiesel from microalgae				
PPC				
Polyols				
Cyclic carbonates				
Formic acid				
CO <sub>2</sub> (food-grade)				
CO <sub>2</sub> (greenhouses, NL)				

# To sum up

- CEMCAP has expanded the knowledge base for future CCS deployment
- CEMCAP delivers a techno-economic decision base for retrofittable CO<sub>2</sub> capture from cement
  - The framework and results are suitable for in-house evaluations of CCUS in the cement sector. Use them!
- CEMCAP has provided 5 candidate technologies for CO<sub>2</sub> capture demos in the cement sector
  - Presentations on Norcem and LEILAC projects later today
- Funding and industrial ownership required for demonstration
- Business models required for moving to full scale CCS



# CEMCAP Partners

## Cement Producers



**HEIDELBERGCEMENT**

## Technology providers



## R&D providers



Coordinated by SINTEF



**CEMCAP**   
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## More about CEMCAP

Sign up for our final webinars on October 29-31: [www.sintef.no/cemcap](http://www.sintef.no/cemcap)

CEMCAP deliverables repository: [www.zenodo.org/communities/cemcap/](http://www.zenodo.org/communities/cemcap/)

Twitter: @CEMCAP\_CO2

