Horizon2020 CCS projects clustering event
March 14 2016, INEA, Brussels

CEMCAP – preparing the grounds for retrofit CO_2 capture from cement plants

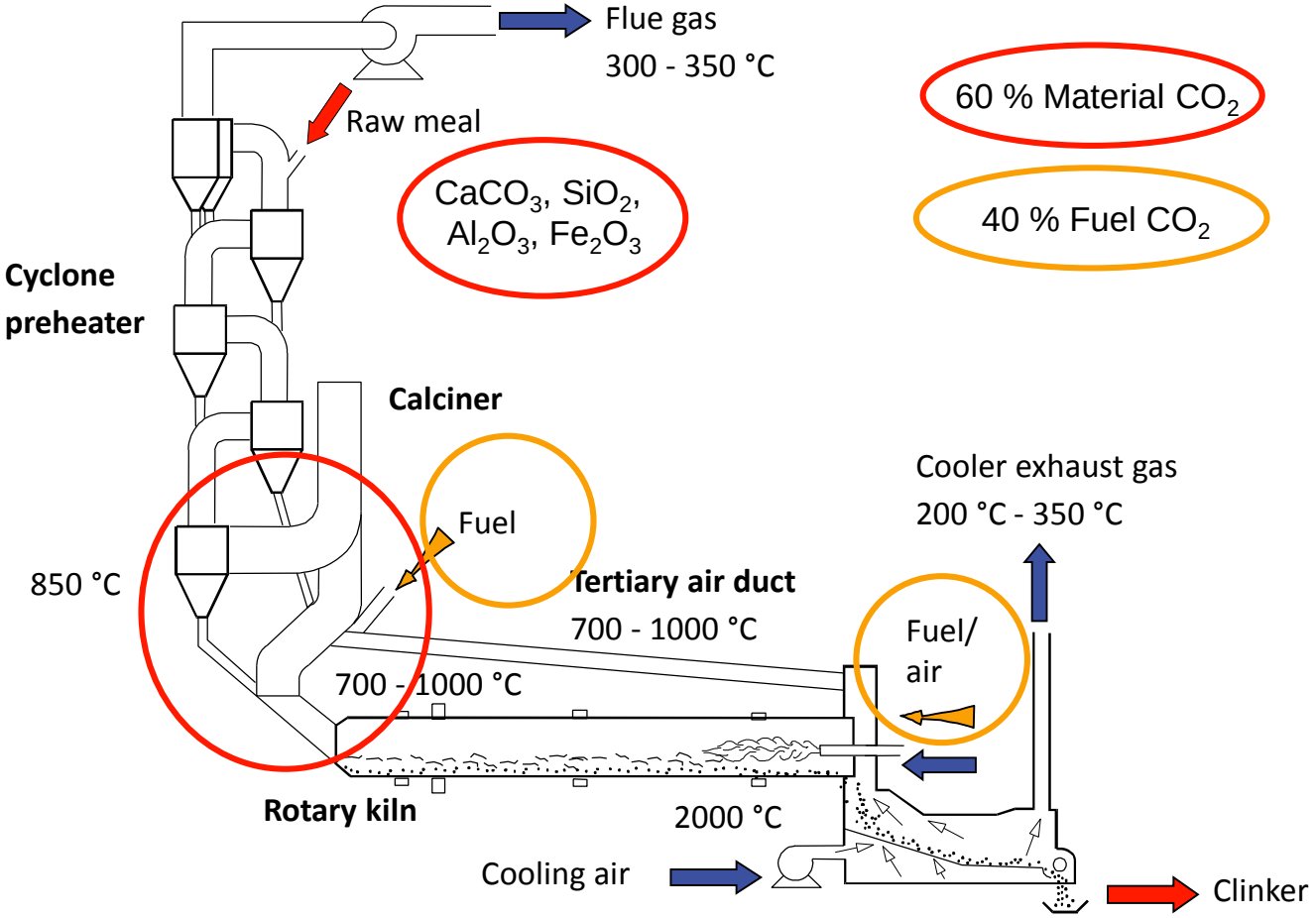
Kristin Jordal
SINTEF Energy Research

CEMCAP

Co-funded by the European Union

CO_2 emissions in the cement industry

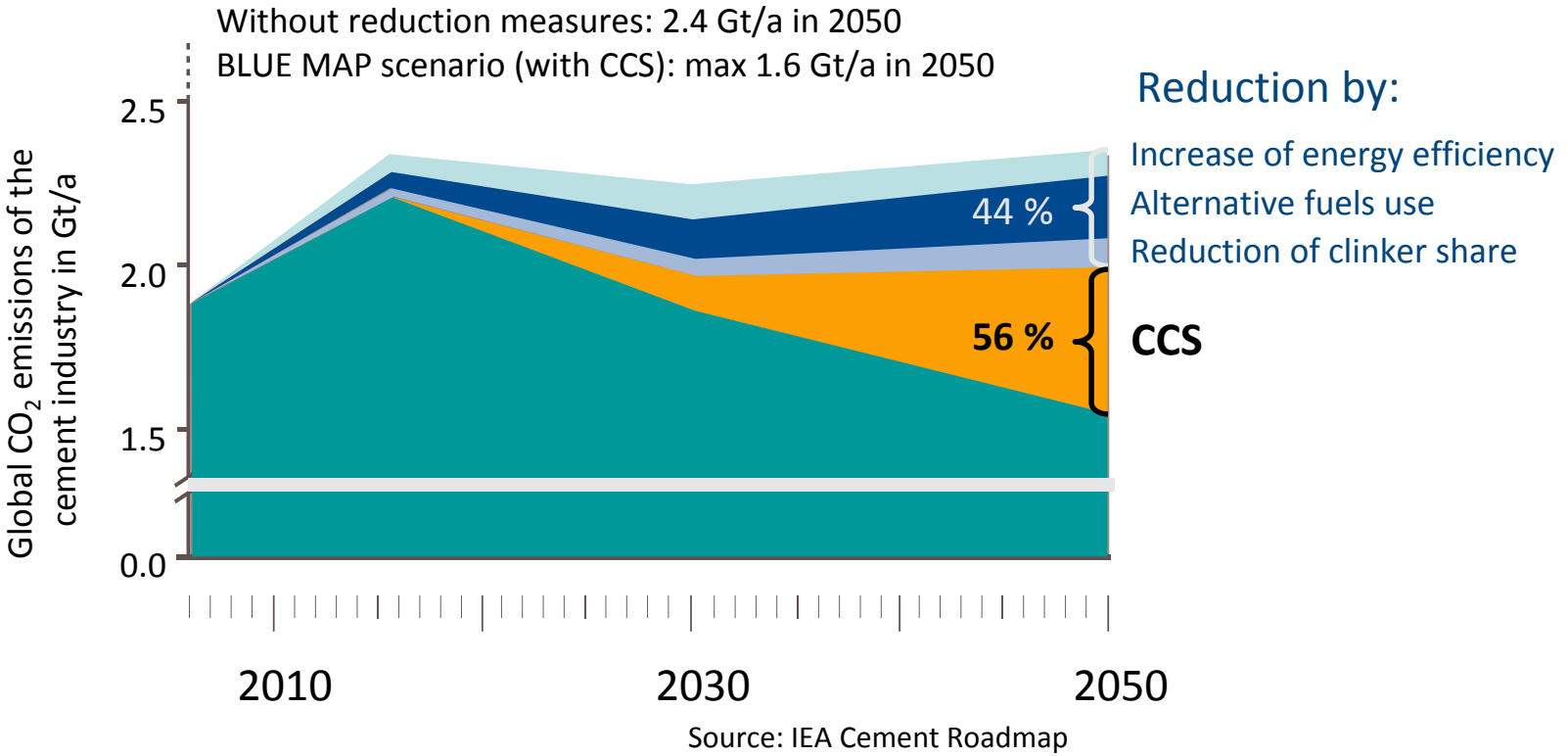
- Cement production constitute ~5% of global anthropogenic CO_2 emissions
- In 2013 ~ 20% of global CO_2 emissions from cement production originated from Europe



CEMCAP

Co-funded by the European Union

The need for CCS in Cement production



Source: IEA Cement Roadmap

- IEA target for 2050: 50 % of all cement plants in Europe, Northern America, Australia and East Asia apply CCS
- Cement plants typically have a long lifetime (30-50 years or more) and very few (if any) are likely to be built in Europe → Retrofit

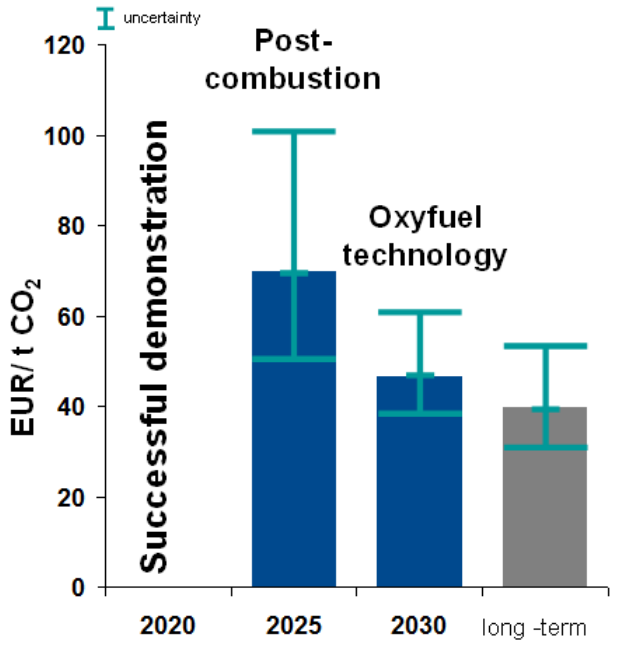
CEMCAP

Co-funded by the European Union

CCS challenges as seen by the cement industry

Challenges of carbon capture

- Significant increase of production costs
- Currently, the legal and economic conditions of these technologies would impair the competiveness of cement production.
- CO_2 storage or reuse strategy and infrastructure missing
- Oxyfuel still requires R&D
- Post-combustion requires further development of high performance capture materials to reduce energy demand



ecra

CEMCAP

Co-funded by the European Union

CEMCAP objectives (1)

The **primary objective of CEMCAP** is

To prepare the ground for large-scale implementation of CO_2 capture in the European cement industry

To achieve this objective, **CEMCAP will**

Leverage to TRL6 for cement plants the oxyfuel capture technology and three fundamentally different post combustion capture technologies, all of them with a targeted capture rate of 90%.

Identify the CO_2 capture technologies with the greatest potential to be retrofitted to existing cement plants in a cost- and resource-effective manner, maintaining product quality and environmental compatibility.

Formulate a techno-economic decision-basis for CO_2 capture implementation in the cement industry, where the current uncertainty regarding CO_2 capture cost is reduced by at least 50%.

Co-funded by the European Union

CEMCAP metrics

- Project coordinator: SINTEF Energy Research
- Duration: May 1st 2015 – October 31st 2018 (42 months)
- Budget: € 10 million
- EC contribution € 8.8 million
- Swiss government contribution: CHF 0.7 million
- Industrial financing: € 0.5 million
- Number of partners: 15

CEMCAP

Co-funded by the European Union

CEMCAP Consortium

Cement Producers

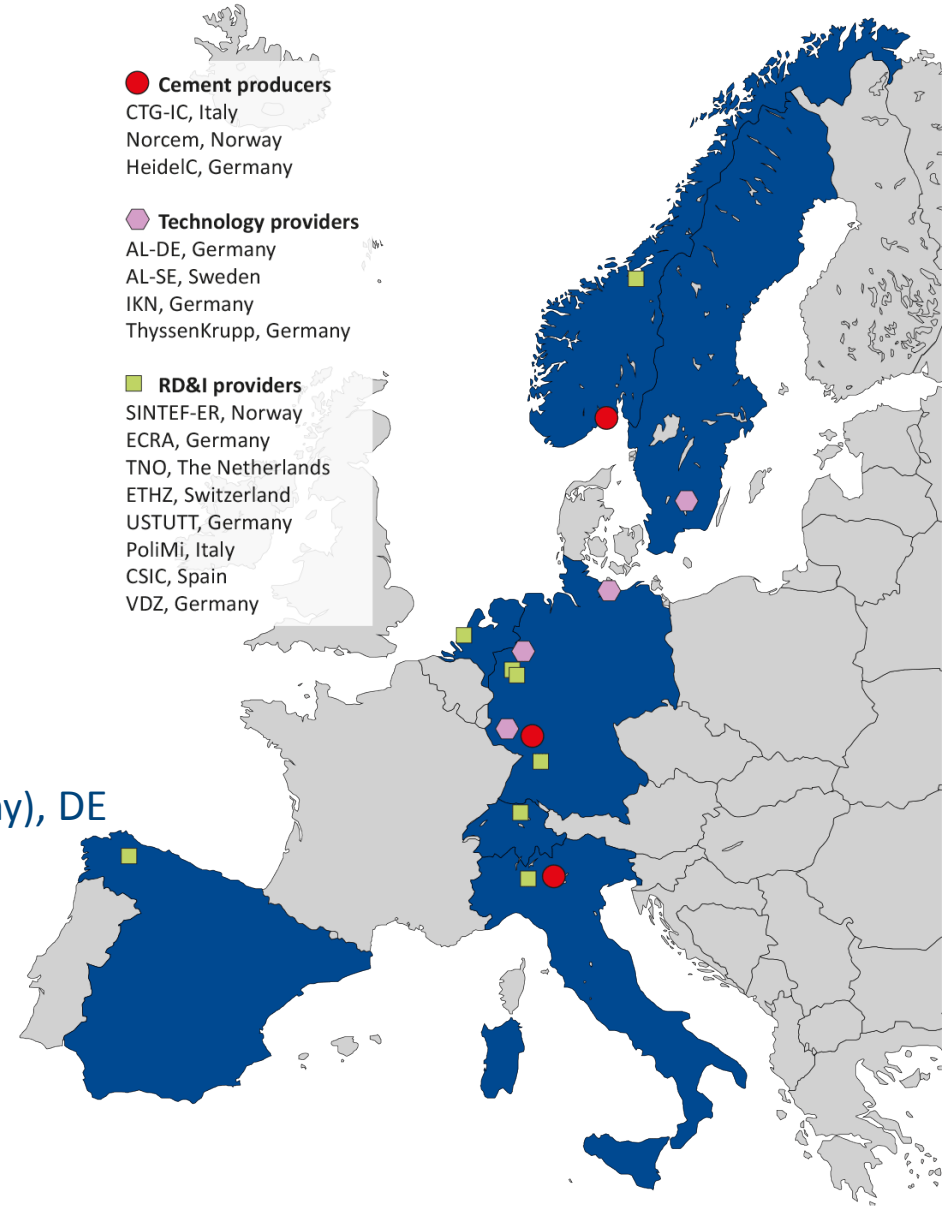
CTG (Group Technical Centre of Italcementi), IT
Norcem, NO
HeidelbergCement, DE

Technology Providers

Alstom Carbon Capture* (AL-DE), DE
Alstom Power Sweden* (AL-SE), SE
IKN, DE
ThyssenKrupp Industrial Solutions, DE

Research Partners

SINTEF Energy Research, NO
ECRA (European Cement Research Academy), DE
TNO, NL
EHTZ, CH
University of Stuttgart, DE
Politecnico di Milano, IT
CSIC, ES
VDZ, DE

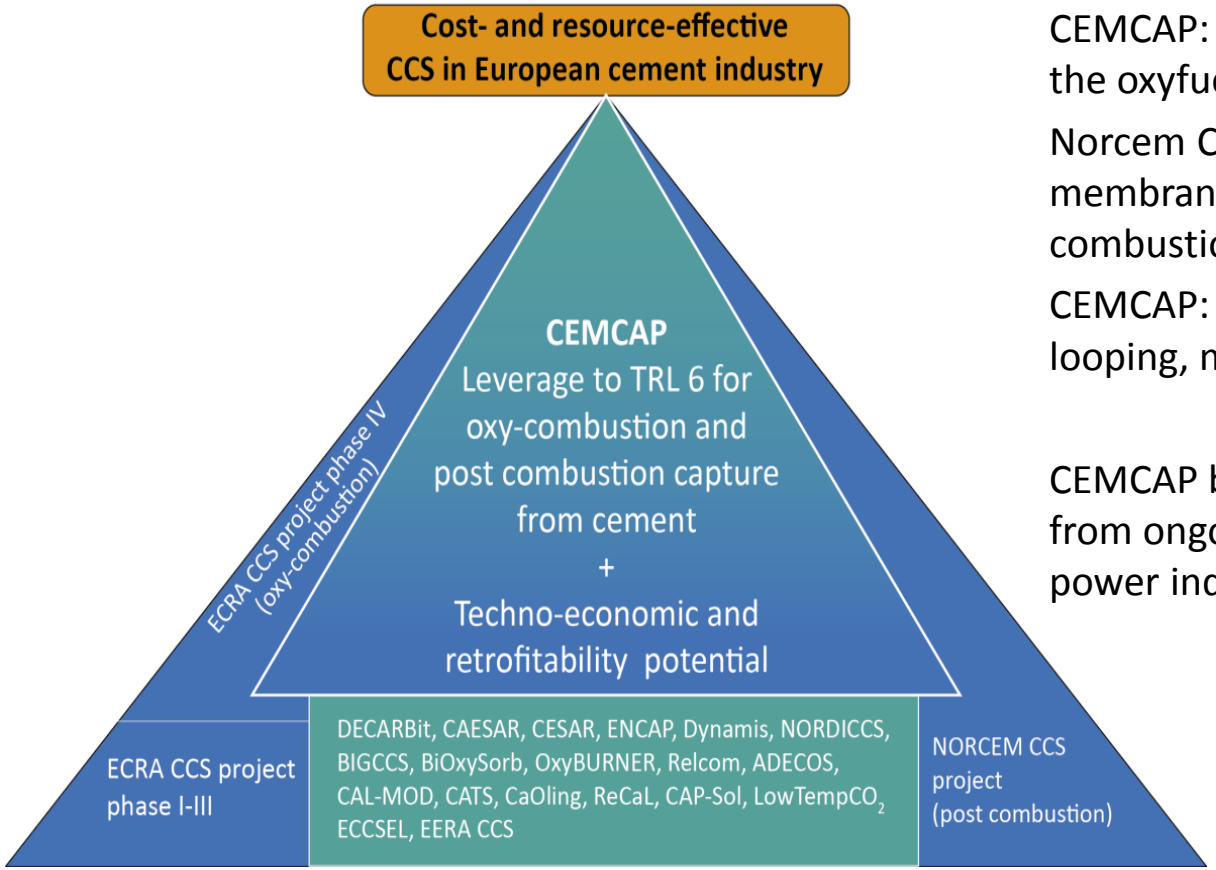


*Aquired by GE Power, names will change

CEMCAP

Co-funded by the European Union

CEMCAP relation to Norcem and ECRA CCS projects



ECRA CCS project: focusing on oxyfuel retrofit in its current phase IV

CEMCAP: testing of three key components for the oxyfuel plant

Norcem CCS project: Testing of amine, membrane, solid sorbent, Ca-looping (post-combustion)

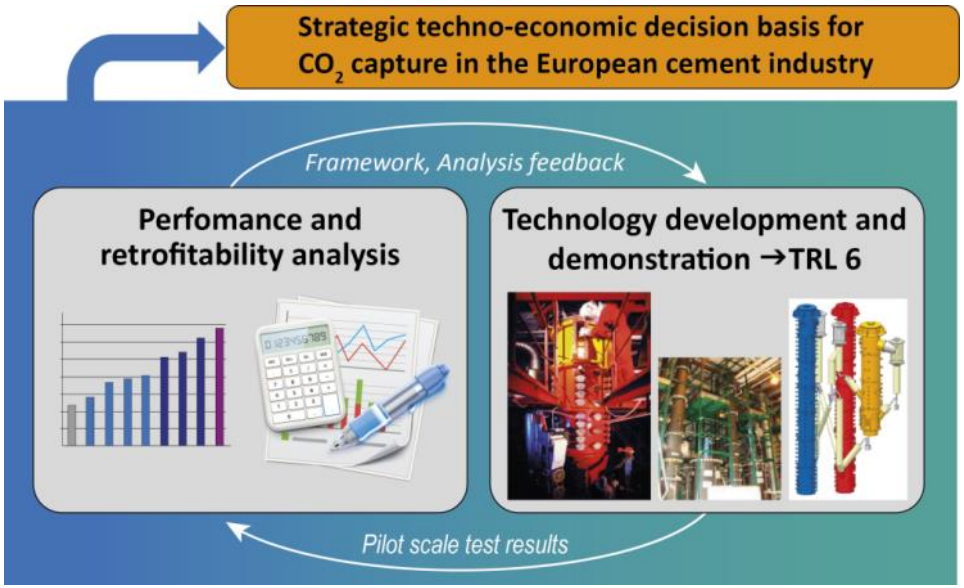
CEMCAP: testing of chilled ammonia, Ca-looping, membrane-assisted CO_2 liquefaction

CEMCAP base: competence and knowledge from ongoing and concluded CCS projects for power industry

CEMCAP

Co-funded by the European Union

CEMCAP approach: iteration between analytical and experimental research



Analytical work

Capture process simulations

Simulations of full cement plants (kilns) with CO_2 capture

Cost estimations/benchmarking

Retrofitability analysis

Experimental work

Testing of three components for oxyfuel capture

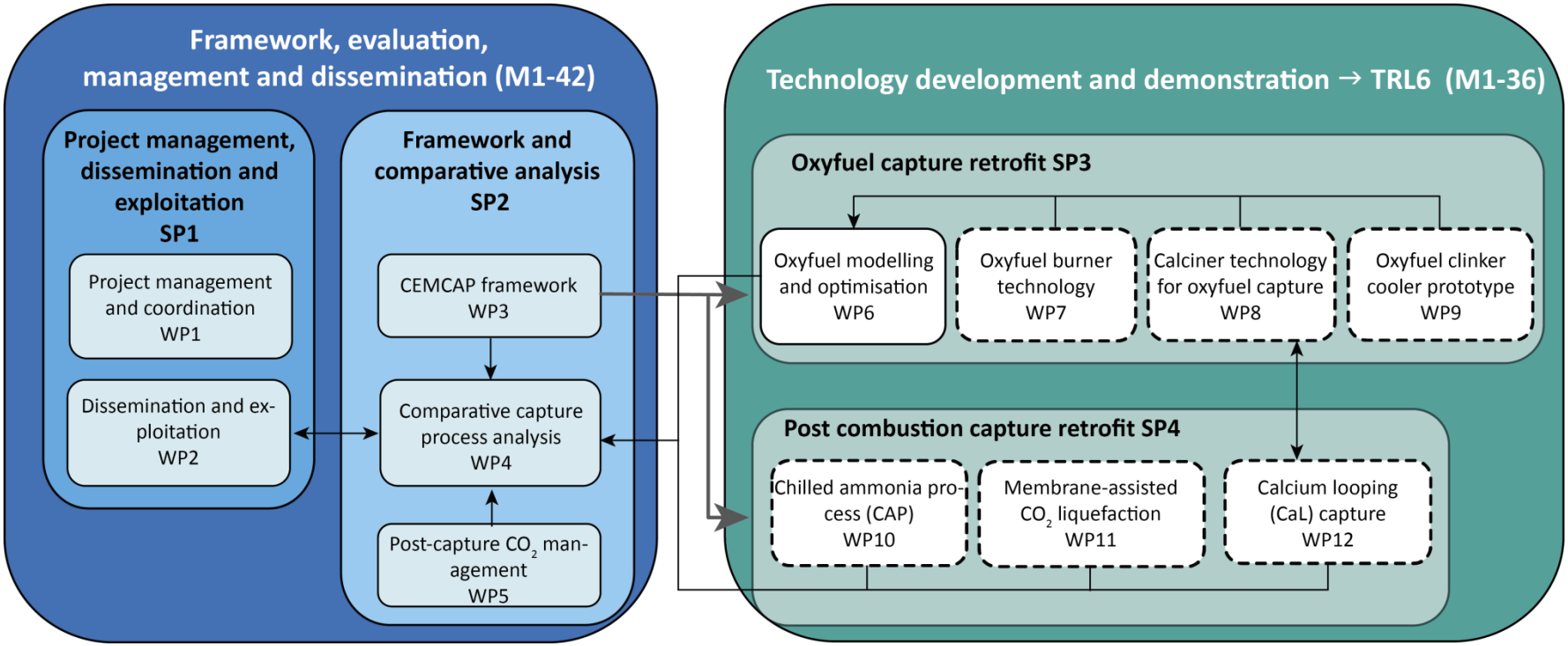
Testing of three different post-combustion capture technologies

~10 different experimental rigs

CEMCAP

Co-funded by the European Union

Project structure



CEMCAP

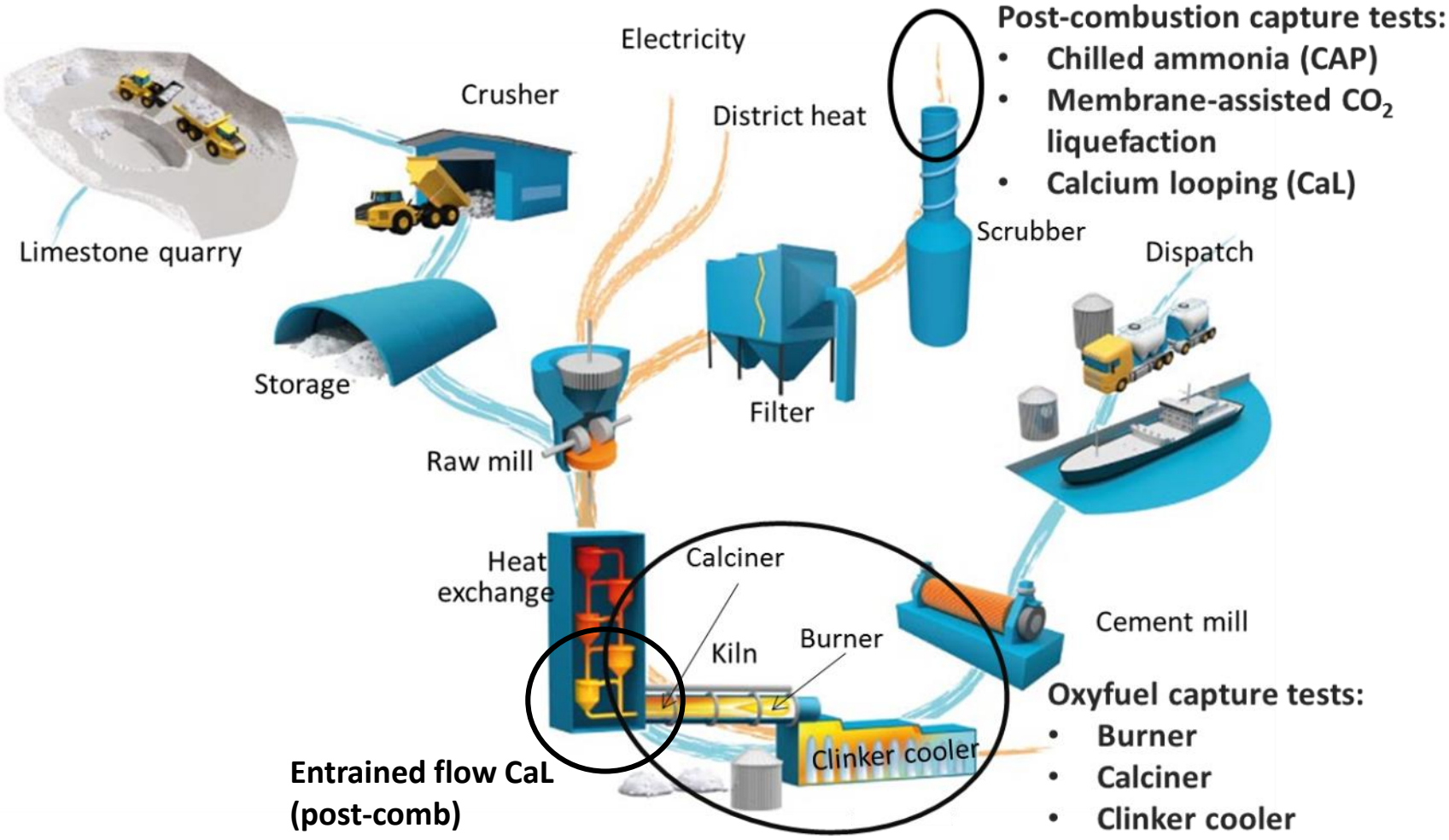
Co-funded by the European Union

CEMCAP framework: Reference plant

- Cement plants differ in size, process technology, operational mode, fuel mix, raw material composition influencing energy efficiency, flue gas characteristics etc.
- A reference kiln system has been defined, based on Best Available Techniques level including
  - 5-stage cyclone preheater
  - Calciner with tertiary air duct
  - Modern grate clinker cooler
- Representative average values of European cement plants define the key data:
  - Plant Size: 3000 t/d (1 Mt clinker/y)
  - Annual cement production: 1.36 Mt/y
  - Clinker/cement ratio: 73.7 %
  - 320 days of non-stop operation (85 % capacity rate), typcially 3-4 weeks of winter revison
- The reference plant without CO_2 capture will be the basis for performance evaluation of all CEMCAP technologies (cost, energy consumption, CO_2 quality…)

Co-funded by the European Union

Technologies to be tested in CEMCAP



CEMCAP

Co-funded by the European Union

Technologies to be tested - oxyfuel

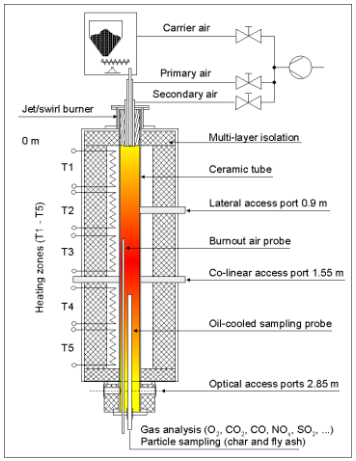
Oxyfuel burner

Existing 500 kWth oxyfuel rig at USTUTT is being modified for CEMCAP

Partners: USTUTT, TKIS, SINTEF-ER

Calciner test rig

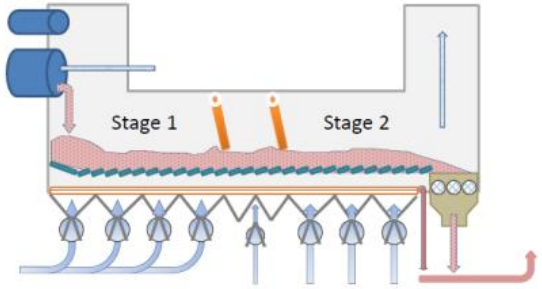
Existing <50 kWth entrained flow calciner (USTUTT) will be used for oxyfuel calcination tests



Partners: USTUTT, VDZ, IKN, CTG

Clinker cooler

Drawings completed, is being built for on-site testing at HeidelbergCement in Hannover (summer 2016)



Partners: IKN, HeidelC, VDZ

CEMCAP

Co-funded by the European Union

Clinker extraction device installed at HeidelbergCement, Hannover

Pictures from IKN

CEMCAP

Co-funded by the European Union

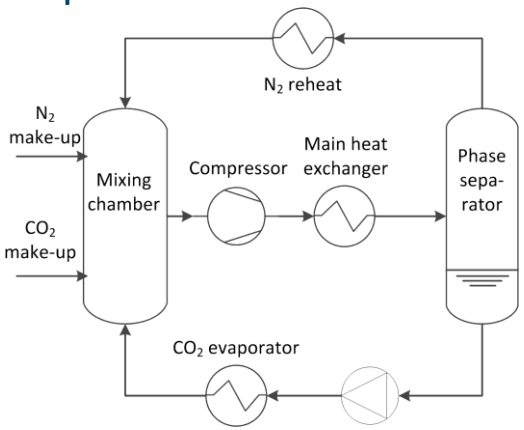
Technologies to be tested – post-combustion capture

Chilled Ammonia Process (CAP)
Absorber tests ongoing at GE Power Sweden (never tested for such high CO_2 concentrations before, up to 35%)

Partners: ETHZ, GE-SE, GE-DE

Membrane assisted CO_2 liquefaction

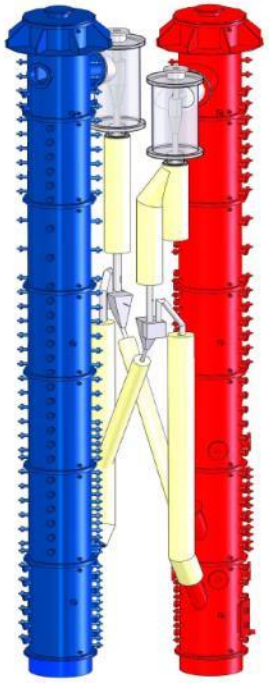
Novel concept, suitable for high CO_2 concentrations
Membrane tests: TNO
Liquef. tests: SINTEF-ER



Partners: TNO, SINTEF-ER

Ca-looping (USTUTT, CSIC rigs)

End-of pipe CaL as well as integrated CaL is developed



Partners: USTUTT, CTG, PoliMi, CSIC, IKN

CEMCAP

Co-funded by the European Union

Characteristics of technologies included in CEMCAP

	Oxyfuel capture	Post combustion capture technologies		
		Chilled ammonia	Membrane-assisted CO_2 liquefaction	Calcium Looping
CO_2 capture principle	Combustion in oxygen (not air) gives a CO_2-rich exhaust	NH_3/water mixture used as liquid solvent, regenerated through heat addition	Polymeric membrane for exhaust CO_2 enrichment followed by CO_2 liquefaction	CaO reacts with CO_2 to from $CaCO_3$, which is regenerated through heat addition
Cement plant integration	Retrofit possible through modification of burner and clinker cooler	Retrofit appears simple, minor modifications required for heat integration	No cement plant modifications. Upstream SOx, NOx, H_2O removal required	Waste from capture process (CaO) is cement plant raw material
Clinker quality	Maintained quality must be confirmed	Unchanged	Unchanged	Clinker quality is very likely to be maintained
CO_2 purity and capture rate	CO_2 purification unit (CPU) needed. High capture rate and CO_2 purity possible (trade-off against power consumption).	Very high CO_2 purity, can also capture NOx, SOx. High capture rate possible.	High CO_2 purity (minor CO_2 impurities present). Trade-off between power consumption and CO_2 purity and capture rate.	Rather high CO_2 purity (minor/moderate CO_2 impurities present). High capture rate.
Energy integration	Fuel demand unchanged. Waste heat recovery + electric power increase.	Auxiliary boiler required + waste heat recovery. Electricity for chilling.	Increase in electric power consumption, no heat integration.	Additional fuel required, enables low-emission electricity generation.

CEMCAP

Co-funded by the European Union

CEMCAP Objectives (2)

Describe the routes for the development required to close technology gaps for CO_2 capture from cement and assist technology suppliers along the related innovation chains.

Identify and follow up minimum five potential innovations springing from CEMCAP research

Publish minimum 40 papers in peer-reviewed journals and at international conferences.

Publish minimum four popular science articles with high international outreach.

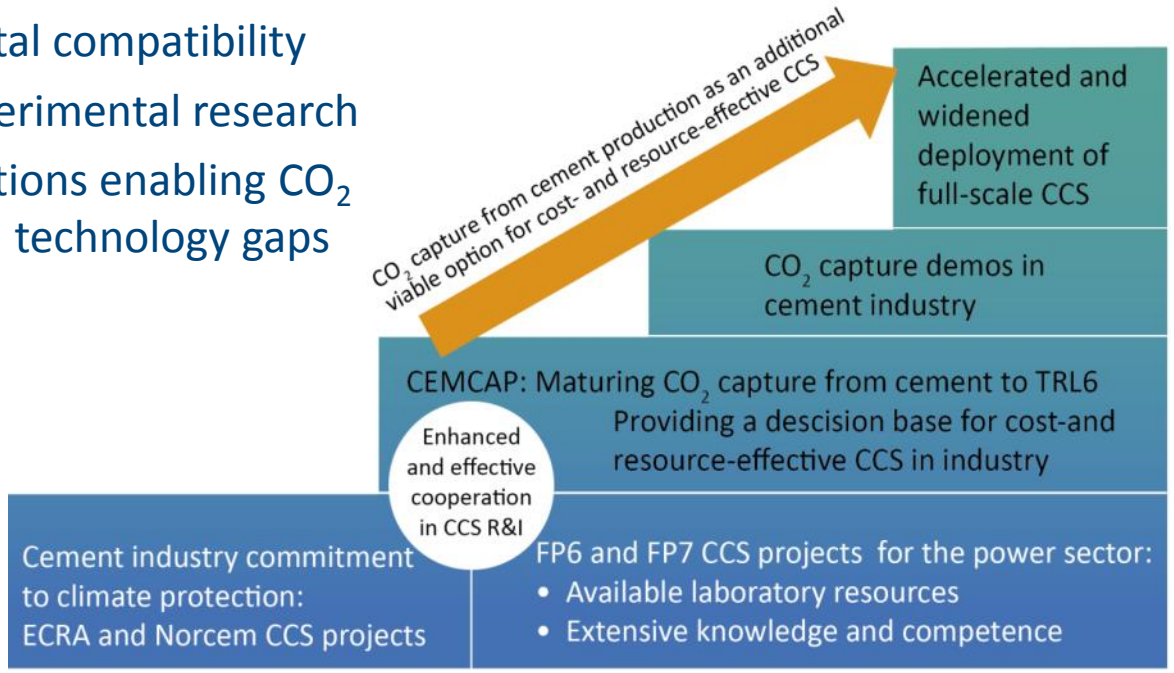
Arrange three workshops about CO_2 capture targeted towards the cement industry.

Co-funded by the European Union

CEMCAP final results

CEMCAP will deliver strategic conclusions for how to progress CO_2 capture from cement plants from pilot-scale testing to demonstration and implementation. The final deliverable will contain:

- A techno-economic decision base for retrofitting CO_2 capture to cement plants with maintained product quality and environmental compatibility
- A high-level summary of the experimental research
- A description of CEMCAP innovations enabling CO_2 capture from cement plants, and technology gaps that must be closed



CEMCAP

Co-funded by the European Union

The first CEMCAP/ECRA workshop

Arranged September 16-17, 2015

Day 1: CCS for cement industry (ECRA, Düsseldorf)

Day 2: Cement production for CO_2 capture researchers (HeidelbergCement, Lixhe)

Workshop summarized in a blog available from the CEMCAP website and #SINTEFenergy

CEMCAP will arrange three workshops about CO_2 capture targeted towards the cement industry. 2nd workshop in M24; 3rd workshop in M42 (public).

CEMCAP Dissemination

CEMCAP progress towards final results are possible to follow through

- Blogs: http://blog.sintefenergy.com/en/, #SINTEFenergy, guest bloggers are invited
- Newsletters (subscribe on cemcap@sintef.no)
- Website: https://www.sintef.no/cemcap/
- Twitter: @cemcap_co2, #CEMCAP
- (Facebook)
- pop-science articles (minimum 4 during the project)
- Conferences:
  - 9 abstracts submitted to GHGT13
  - TCCS9 in 2017 – abstract submission in January 2017. Joint H2020 CCS session?

CEMCAP

Co-funded by the European Union

Scientific publishing

Grant Agreement article **29.1 Obligation to disseminate results**

Unless it goes against their legitimate interests, each beneficiary must — as soon as possible — '**disseminate**' its results by disclosing them to the public by appropriate means (other than those resulting from protecting or exploiting the results), including in scientific publications (in any medium).

29.2 Open access to scientific publications

Each beneficiary must ensure open access (free of charge online access for any user) to all peer-reviewed scientific publications relating to its results. In particular, it must:

(a) as soon as possible and at the latest on publication, **deposit** a machine-readable electronic copy of the published version or final peer-reviewed manuscript accepted for publication in **a repository for scientific publications**;

(b) ensure **open access** to the deposited publication — via the repository — at the latest:

(i) on publication, if an electronic version is available for free via the publisher, or

(ii) within **six months** of publication (twelve months for publications in the social sciences and humanities) in any other case.

(c) ensure open access — via the repository — to the bibliographic metadata that identify the deposited publication.

CEMCAP

Co-funded by the European Union

List of OA journals relevant to CEMCAP (non-exhaustive)

International Journal of Greenhouse Gas Control (Elsevier)

- Open access strategy: Post-print on open access repository after embargo period of **24 months**/paid open access (**USD 3600**)
- Web-page: www.journals.elsevier.com/international-journal-of-greenhouse-gas-control

Energy (Elsevier)

- Open access strategy: Post-print on open access repository after embargo period of **24 month**s/paid open access (**USD 2750**)
- Web-page: www.journals.elsevier.com/energy

Applied Energy (Elsevier)

- Open access strategy: Post-print on open access repository after embargo period of **24 months**/paid open access (**USD 3300**)
- Web-page: www.journals.elsevier.com/applied-energy

Energy Conversion and Management (Elsevier)

- Open access strategy: Post-print on open access repository after embargo period of **24 month**s/paid open access (**USD 2750**)
- Web-page: www.journals.elsevier.com/energy-conversion-and-management

Industrial & Engineering Chemistry Research (ACS)

- Open access strategy: **12 month** embargo/paid open access (**USD1500-4000** for immediate open access)
- Web-page: http://pubs.acs.org/journal/iecred

List of OA journals for CEMCAP (non-exhaustive)

Energy and Environmental Science (RCS)

Open access strategy: Post-print in institutional repository after **12 months** from acceptance/ paid open access **(£1600** for paper, 15% discount under some conditions)

Web-page: http://pubs.rsc.org/en/journals/journalissues/ee

Advances in Cement Research (Thomas Telford, ICE publishing)

Open access strategy: Authors can archive post-print in open repository (i.e. final draft post-refereeing). Publisher's version may be used after 12-month embargo (alternative pay for open access and publishers version is available immediately, cost £1800)

Web-page: http://www.icevirtuallibrary.com/content/serial/adcr

Cement and Concrete Research (Elsevier)

Open access strategy: Post-print on open access repository after embargo period of **24 months**/paid open access (**USD 3300**)

Web-page: http://www.journals.elsevier.com/cement-and-concrete-research/

Energies (MDPI)

Open access strategy: Authors pay **1200 CHF** per peer-reviewed paper published (open access only, no subscriptions)

Web-page: http://www.mdpi.com/journal/energies/apc

Energy Science and Engineering (Wiley Open Access, *not indexed yet*)

Open access strategy: Authors pay **€1410** per peer-reviewed paper published (open access only, no subscriptions, discounts available under certain conditions)

Web-page: http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2050-0505

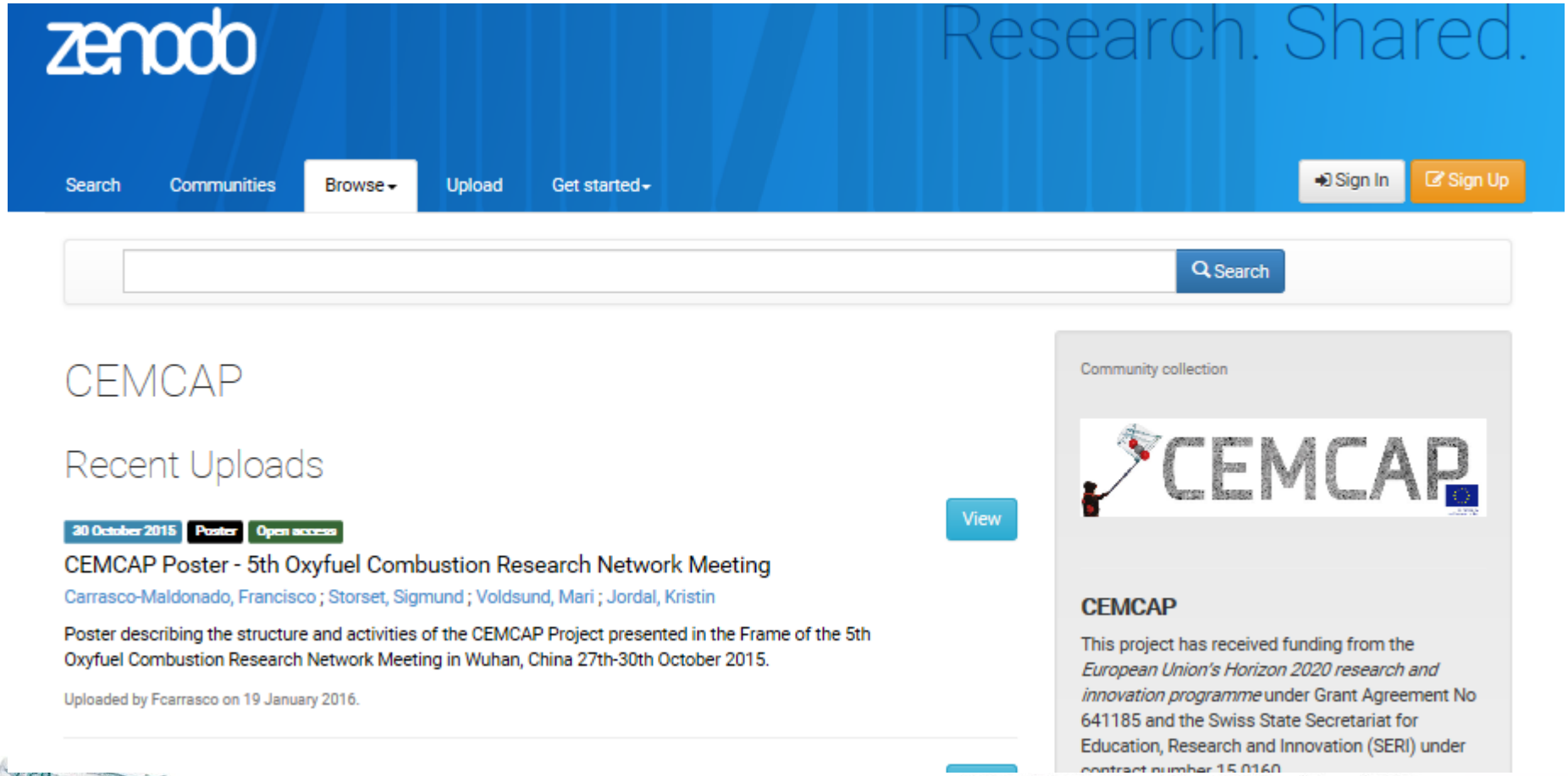
Greenhouse Gases: Science and Technology (Wiley)

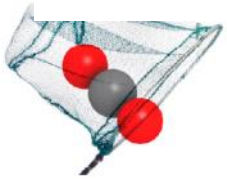
Open access strategy: Self-archiving of accepted (peer-reviewed) version after embargo period of 12 months/immediate open access (**USD3000**).

Web-page: http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2152-3878

Use of zenodo.org for archiving

- CEMCAP community created in zenodo, can harvest from national archives





CEMCAP

Co-funded by the European Union

Thank you for your attention!

Questions?

Acknowledgement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 641185

www.sintef.no/cemcap

Twitter: @CEMCAP_CO2

CEMCAP

Co-funded by the European Union