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CEMCAP – a Horizon 2020 project on CO_2 capture from cement production

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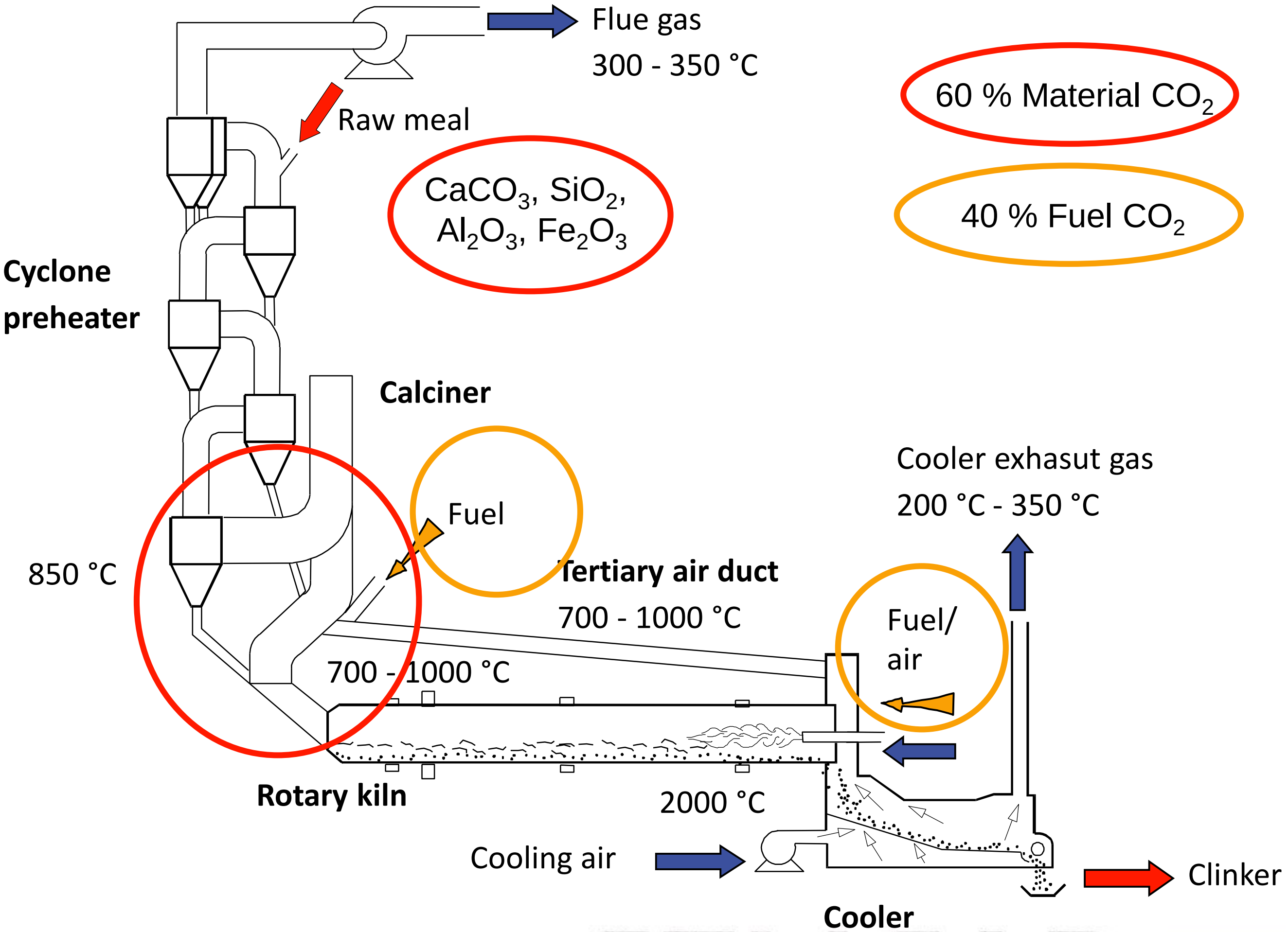
CO_2 emissions in the cement industry

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



Flue gas

300 - 350 °C

Raw meal

$CaCO_3$, SiO_2, Al_2O_3, Fe_2O_3

60 % Material CO_2

40 % Fuel CO_2

Cyclone preheater

Calciner

Fuel

850 °C

Tertiary air duct

700 - 1000 °C

700 - 1000 °C

Cooler exhasut gas

200 °C - 350 °C

Fuel/ air

Rotary kiln

2000 °C

Cooling air

Clinker

Cooler

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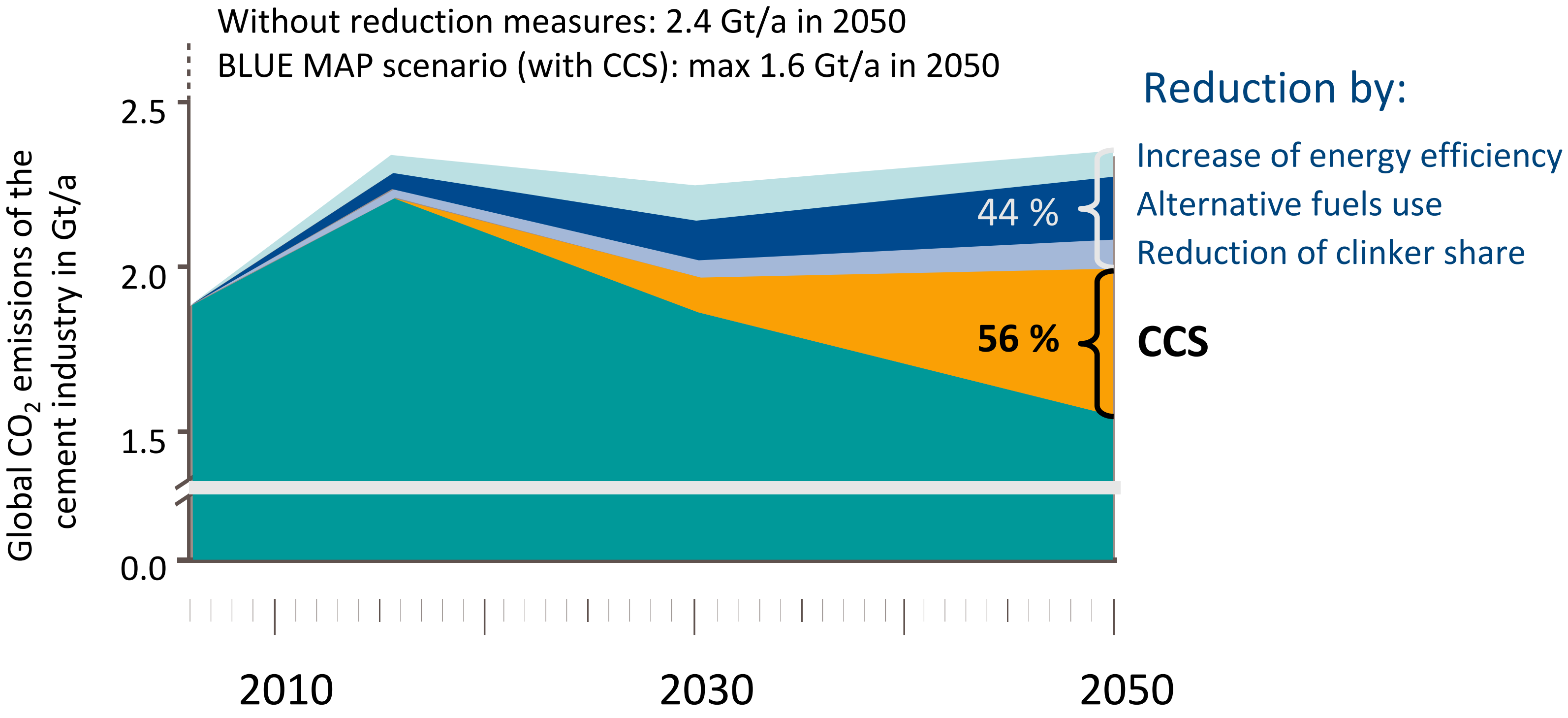
The need for CCS in Cement production



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

The CEMCAP objectives

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%.

CEMCAP metrics

- Horizon2020 project coordinated by 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
- Number of partners: 15

CEMCAP Consortium

Cement Producers

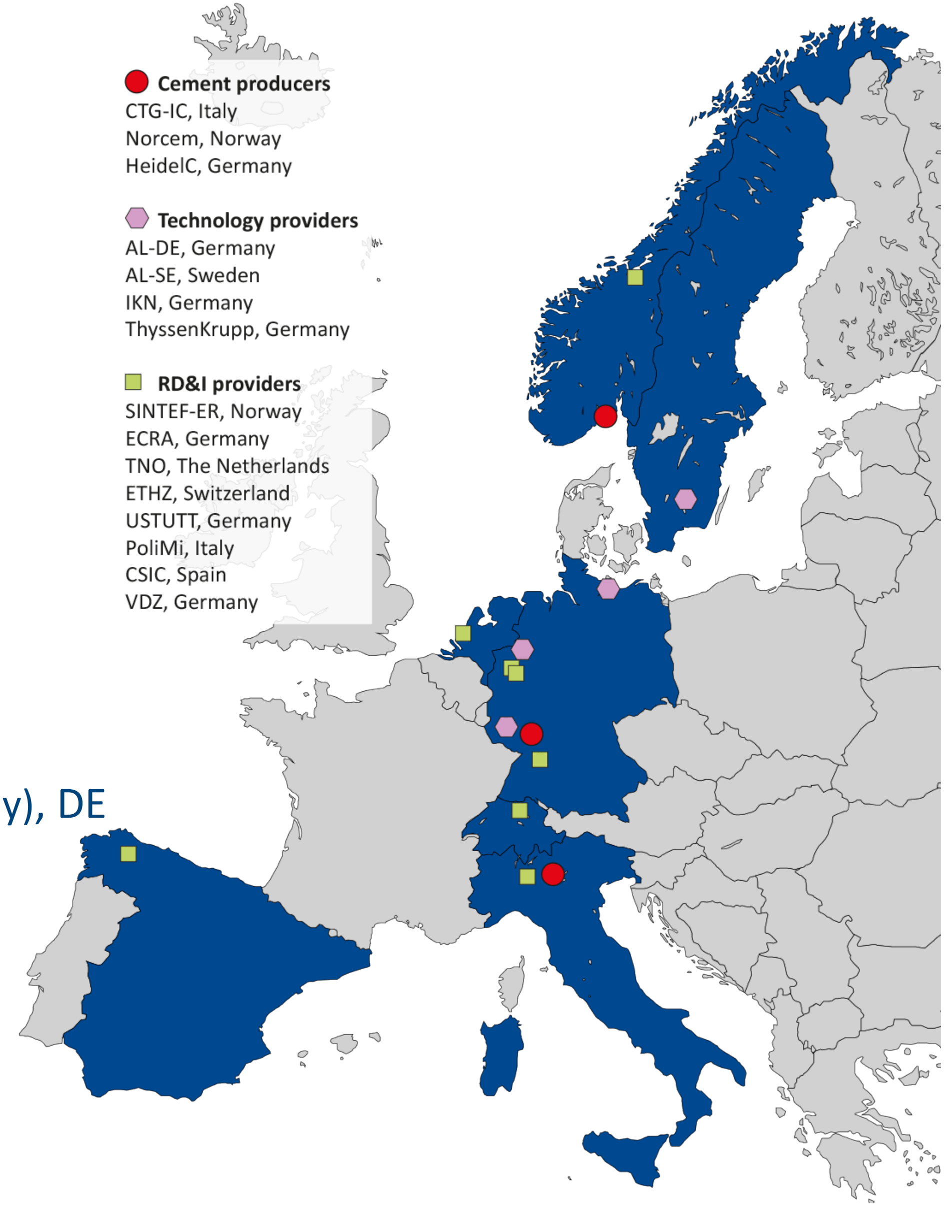
CTG (Group Technical Centre of Italcementi), IT
Norcem, NO
HeidelbergCement, DE

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



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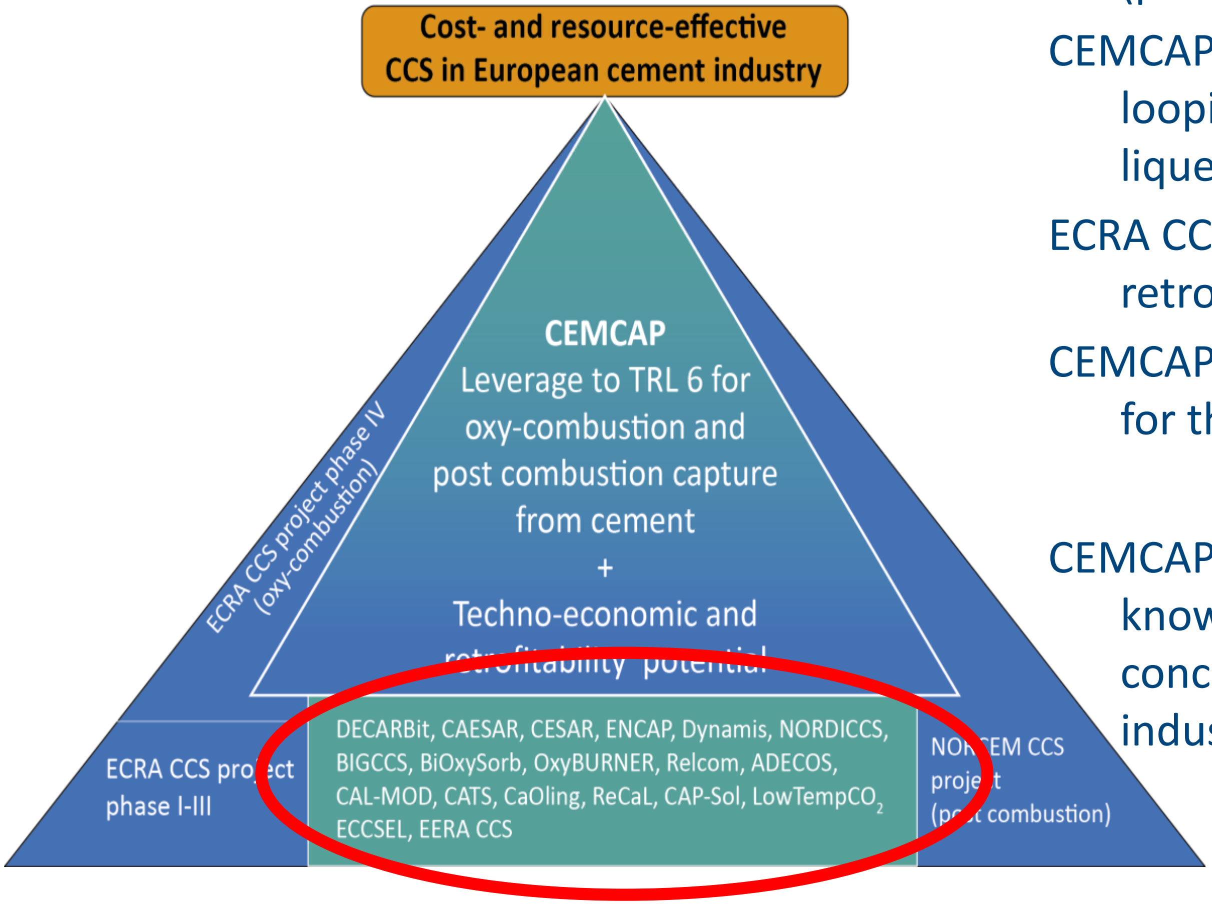
CEMCAP relation to Norcem and ECRA CCS projects



Cost- and resource-effective CCS in European cement industry

CEMCAP
Leverage to TRL 6 for oxy-combustion and post combustion capture from cement
+
Techno-economic and retrofitability potential

ECRA CCS project phase IV (oxy-combustion)

ECRA CCS pro ect phase I-III

DECARBit, CAESAR, CESAR, ENCAP, Dynamis, NORDICCS, BIGCCS, BiOxySorb, OxyBURNER, Relcom, ADECOS, CAL-MOD, CATS, CaOling, ReCaL, CAP-Sol, LowTempCO$_2$, ECCSEL, EERA CCS

NOR EM CCS proje t (p t combustion)

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

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

CEMCAP: testing of three key components for the oxyfuel plant

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

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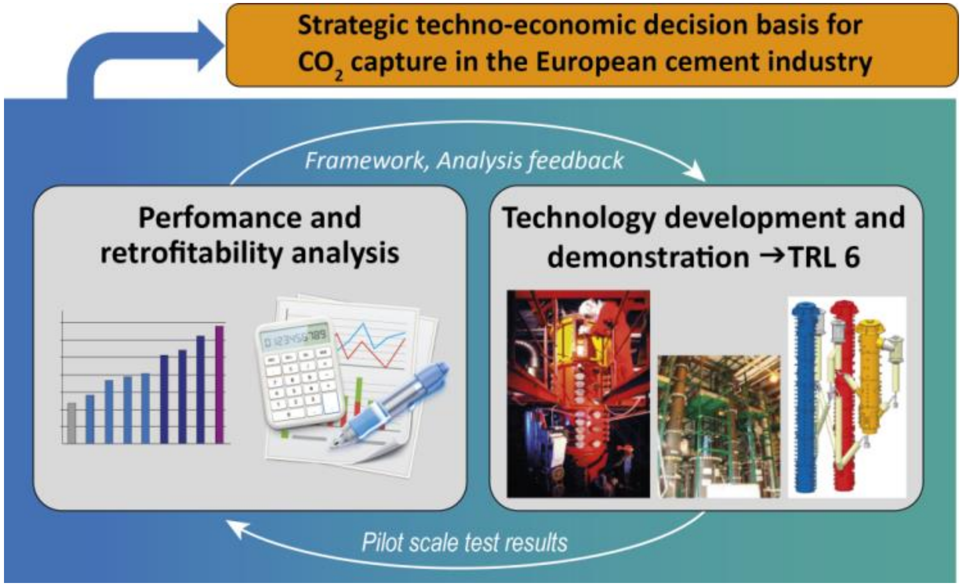
CEMCAP approach: iteration between analytical and experimental research



Strategic techno-economic decision basis for CO_2 capture in the European cement industry

Framework, Analysis feedback

Perfomance and retrofitability analysis

Technology development and demonstration →TRL 6

Pilot scale test results

<u>Analytical work</u>

Capture process simulations

Simulations of full cement plants (kilns) with CO_2 capture

Cost estimations/benchmarking

Retrofitability analysis

<u>Experimental work</u>

Testing of three components for oxyfuel capture

Testing of three different post-combustion capture technologies

~10 different experimental rigs

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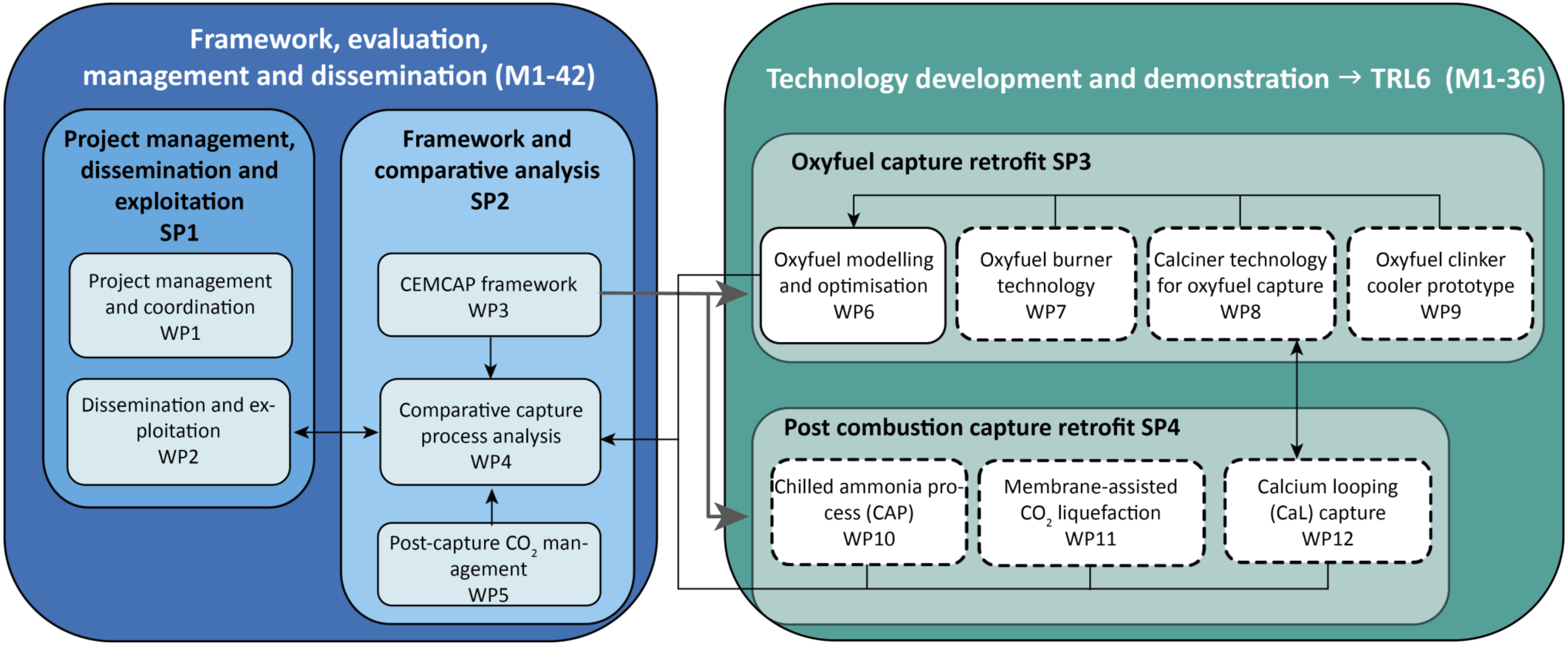
Project structure



Framework, evaluation, management and dissemination (M1-42)

Project management, dissemination and exploitation SP1

Project management and coordination WP1

Dissemination and exploitation WP2

Framework and comparative analysis SP2

CEMCAP framework WP3

Comparative capture process analysis WP4

Post-capture CO_2 management WP5

Technology development and demonstration → TRL6 (M1-36)

Oxyfuel capture retrofit SP3

Oxyfuel modelling and optimisation WP6

Oxyfuel burner technology WP7

Calciner technology for oxyfuel capture WP8

Oxyfuel clinker cooler prototype WP9

Post combustion capture retrofit SP4

Chilled ammonia process (CAP) WP10

Membrane-assisted CO_2 liquefaction WP11

Calcium looping (CaL) capture WP12

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.

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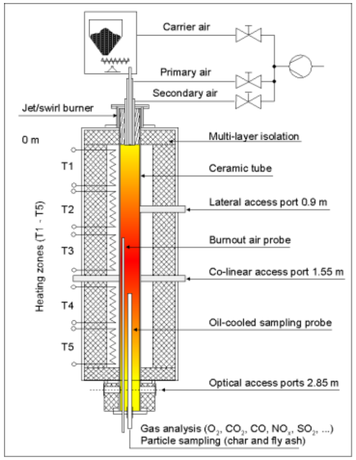
Technologies to be tested - oxyfuel

Oxyfuel burner
Existing 500 kWth oxyfuel burner at USTUTT to be modified for CEMCAP

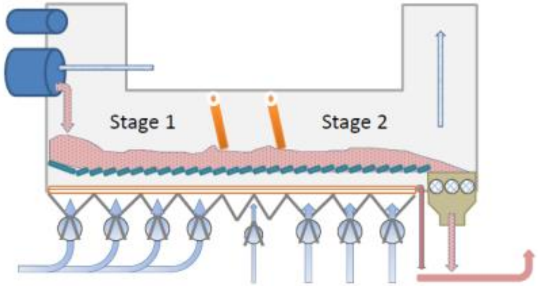
Partners: USTUTT, TKIS, SINTEF-ER

Calciner test rig
Existing <50 kWth entrained flow calciner (USTUTT) to be used for oxyfuel calcination tests



Partners: USTUTT, VDZ, IKN, CTG

Clinker cooler To be designed and built for on-site testing at HeidelbergCement in Hannover



Partners: IKN, HeidelC, VDZ

Technologies to be tested – post-combustion capture

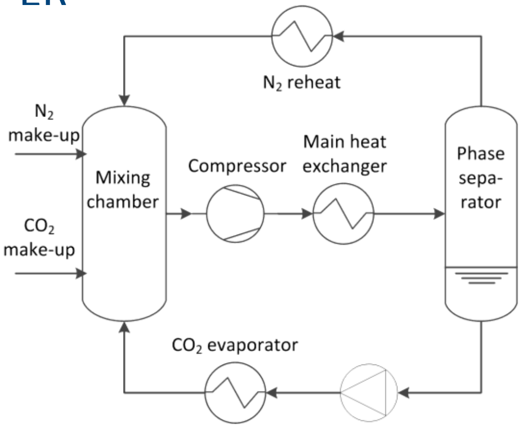
Chilled Ammonia Process (CAP)
Tests at Alstom Power Sweden (never tested for such high CO_2 concentrations before)

Partners: ETHZ, AL-SE, AL-DE

Membrane assisted CO_2 liquefaction

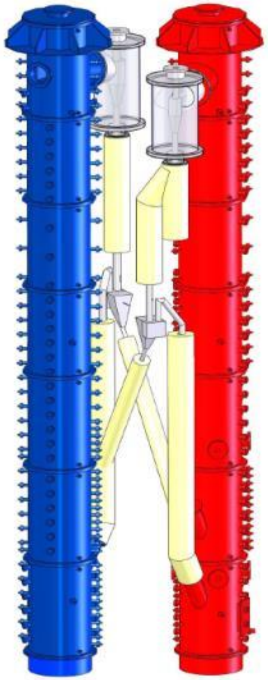
Membrane tests: TNO

Liquefaction tests: SINTEF-ER



Partners: TNO, SINTEF-ER

Ca-looping (USTUTT, CSIC rigs)



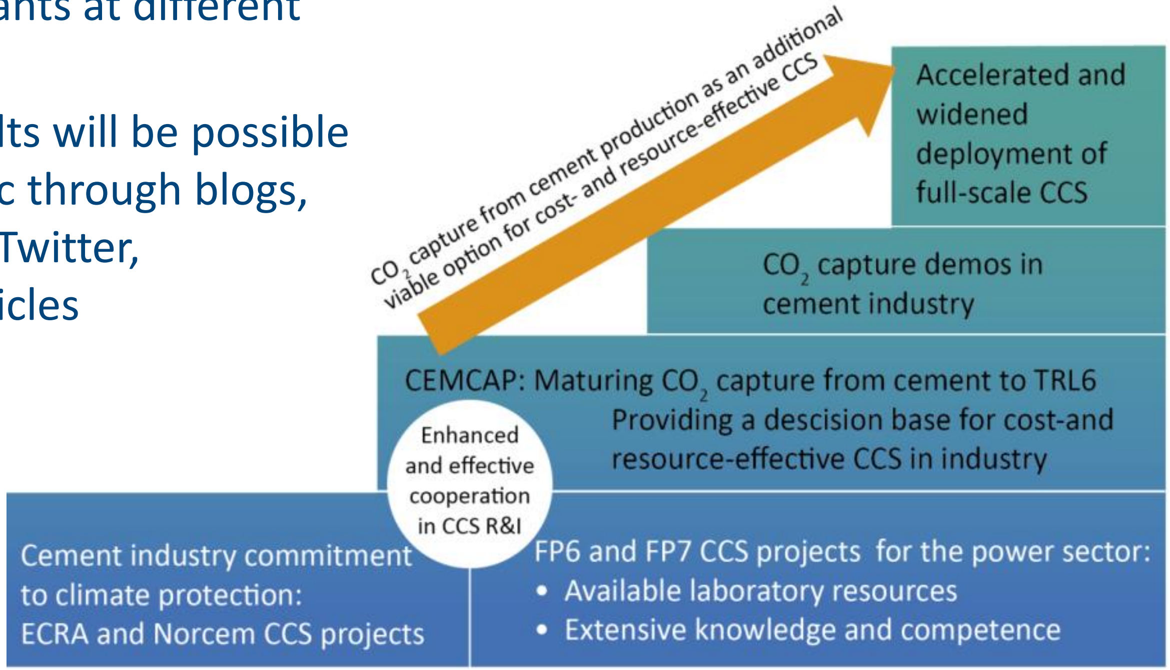
Partners: USTUTT, CTG, PoliMi, CSIC, IKN

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

Recommendations will be given for different scenarios (i.e. different types of cement plants at different locations in Europe)

CEMCAP progress towards final results will be possible to follow for the interested public through blogs, newsletters, website, Facebook, Twitter, conferences and pop-science articles



CO_2 capture from cement production as an additional viable option for cost- and resource-effective CCS

Accelerated and widened deployment of full-scale CCS

CO_2 capture demos in cement industry

CEMCAP: Maturing CO_2 capture from cement to TRL6
Providing a descision base for cost-and resource-effective CCS in industry

Enhanced and effective cooperation in CCS R&I

Cement industry commitment to climate protection:
ECRA and Norcem CCS projects

FP6 and FP7 CCS projects for the power sector:
- Available laboratory resources
- Extensive knowledge and competence

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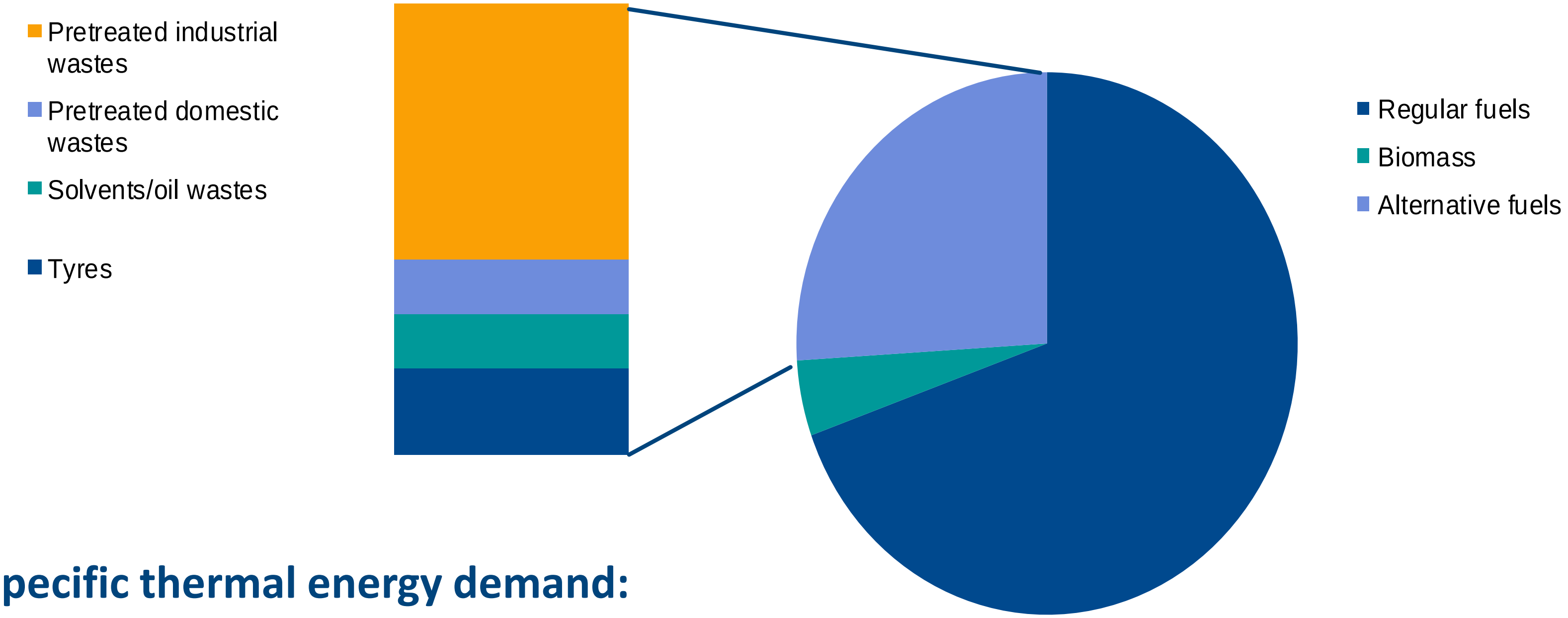
CEMCAP framework: Reference plant

- Cement plants differ in size, process technology, operational mode, fuel mix, raw material composition influencing energy efficiency, flue gas characteristics etc.
- Reference kiln system is based on Best Available Techniques level including
  - 5-stage cyclone preheater
  - Calciner with tertiary air duct
  - Modern grate cooler

- Representative average values of European cement plants define the key facts:
  - Plant Size: 3000 t/d (1 Mt clinker/y)
  - Annual cement production: 1.36 Mt clinker/y
  - Clinker/cement ratio: 73.7 %
  - 320 days of non-stop operation (85 % capacity rate), typcially 3-4 weeks of winter revison

Thermal energy demand of the cement industry



Specific thermal energy demand:

3,280 kJ/kg clinker (annual average)

30 % substitution rate

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Flue gas characteristics – CO_2 emissions

Reference plant – CO_2 emissions	
Spec. indirect CO_2 from electricity	0.049 - 0.068 t CO_2/t cement
Spec. direct CO_2 from clinker production (incl. biogenic CO_2)	0.828 t CO_2/t clinker EU-average: 0.862 t CO_2/t clinker
Total spec. CO_2 emissions incl. electricity	0.66 – 0.68 t CO_2/t cement

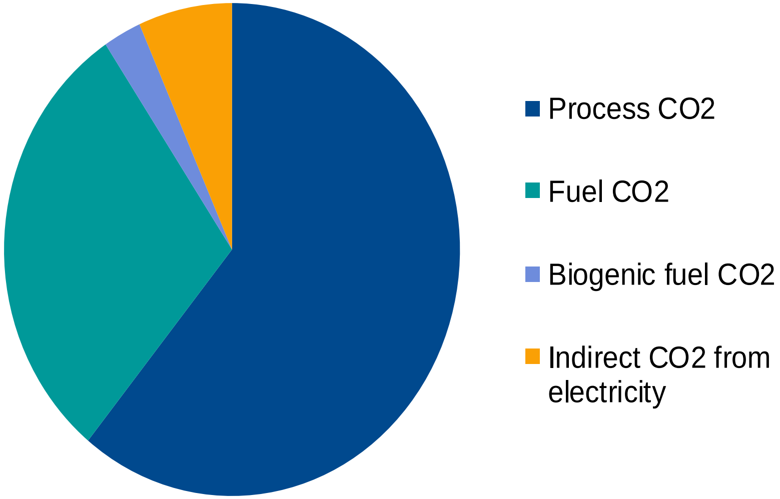
- CO_2 content in flue gas mainly influenced by thermal energy efficiency, fuel and raw material composition.
- Reference case:

  828,000 tCO_2/y per plant

  ~ 2550 tCO_2/d
- Total net CO_2 emissions in 2013:

  Germany: 15.7 Mt

  EU: 110 Mt



Examples for flue gas compositions

Component	**Exhaust gas**			
	Conventional	From oxyfuel combustion		From Post-combustion
		Min	Max	
CO_2	14 – 35 vol.%	95 vol.%	99.9 vol.%	> 99.0 vol.%
O_2	3 – 14 vol.%	1.2 vol.%	0.001 vol.%	
N_2	Rest	3.4 vol.%	-	
Ar		0.4 vol.%	-	
NO_x	0. 5 – 0.8 g/m^3	< 0.55 g/m^3	< 0.55 g/m^3	
SO_2	50 – 400 mg/m^3	< 4 mg/m^3	< 4 mg/m^3	
CO	0.1 – 2 g/m^3	< 0.3 g/m^3	-	
H_2O	6 – 10 vol.%	-	-	
HCl	< 20 mg/m^3	-	-	

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Thank you for your attention!

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