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european cement research academy

Carbon Dioxide Control Technologies for the Cement Industry

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GCEP Workshop “Carbon Management in
Manufacturing Industries”

Stanford University, 15/16 April 2008

Carbon Dioxide Control Technologies for the Cement Industry

1. Introduction
2. The cement clinker burning process
3. Assessment of carbon dioxide control technologies
 - 3.1 Pre-combustion technologies
 - 3.2 Oxyfuel technology
 - 3.3 Post-combustion technologies
4. Preliminary research results (Oxyfuel technology)
 - 4.1 Impact on raw meal decarbonation
 - 4.2 Modeling of the clinker burning process with Oxyfuel operation



The German Cement Works Association (VDZ)



↑ The Research Institute of the Cement Industry,
Düsseldorf / Germany

Activities:

- Mortar and concrete
- Chemistry and mineralogy
- Environmental expertise
- Plant technology investigations
- Environmental measurements
- Certification
- Knowledge transfer

For further information: www.vdz-online.de

vdz.

The European Cement Research Academy (ECRA)

- has been founded by VDZ in 2004
- Members (> 40) are cement companies and associations from Europe, Asia, Australia, US
- objectives
 - know how transfer
 - joint research
- activities
 - seminars and workshops
 - research programmes
 - carbon capture technologies for the cement industry
 - continuous measurement of biomass CO₂ in stack gases

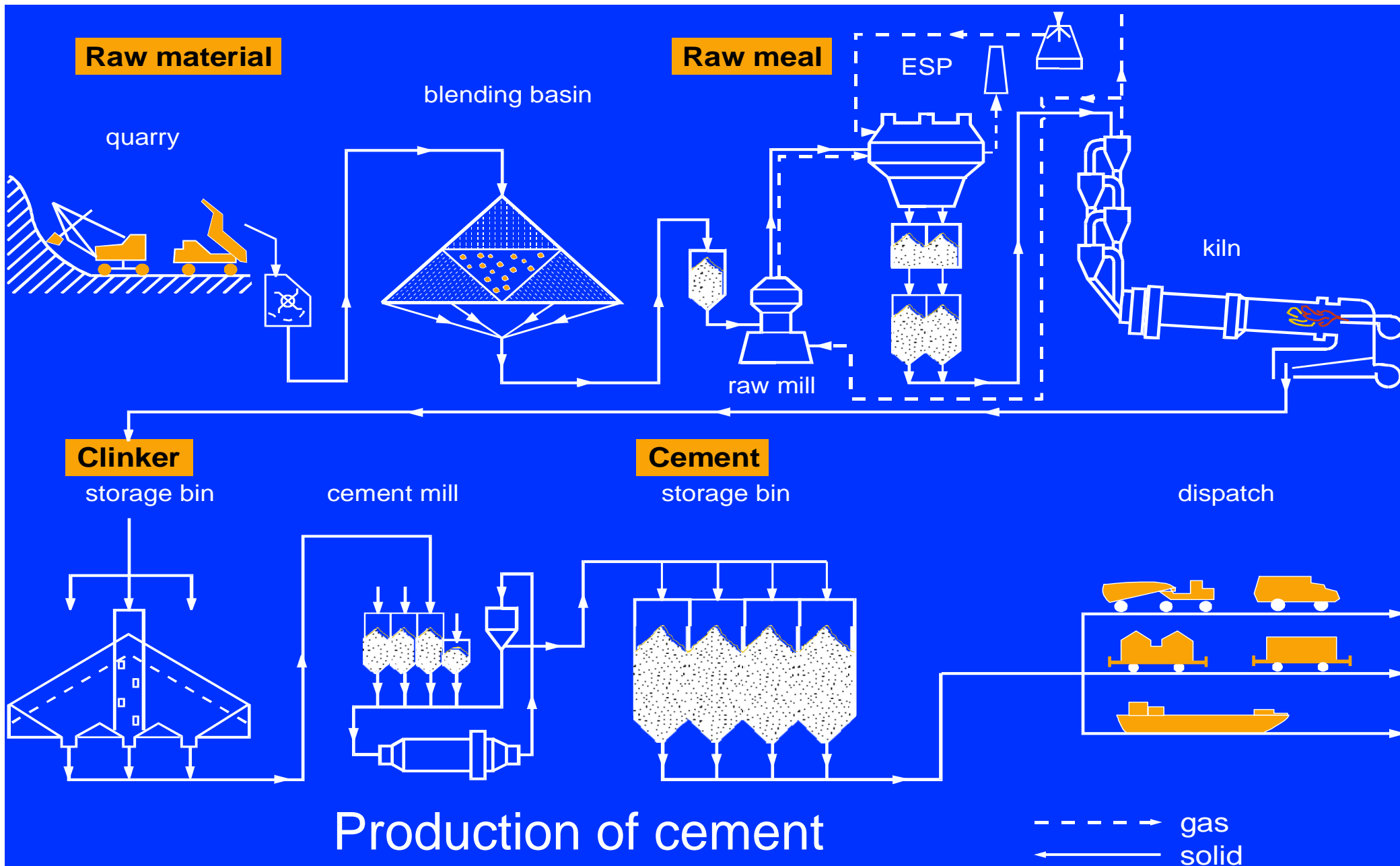


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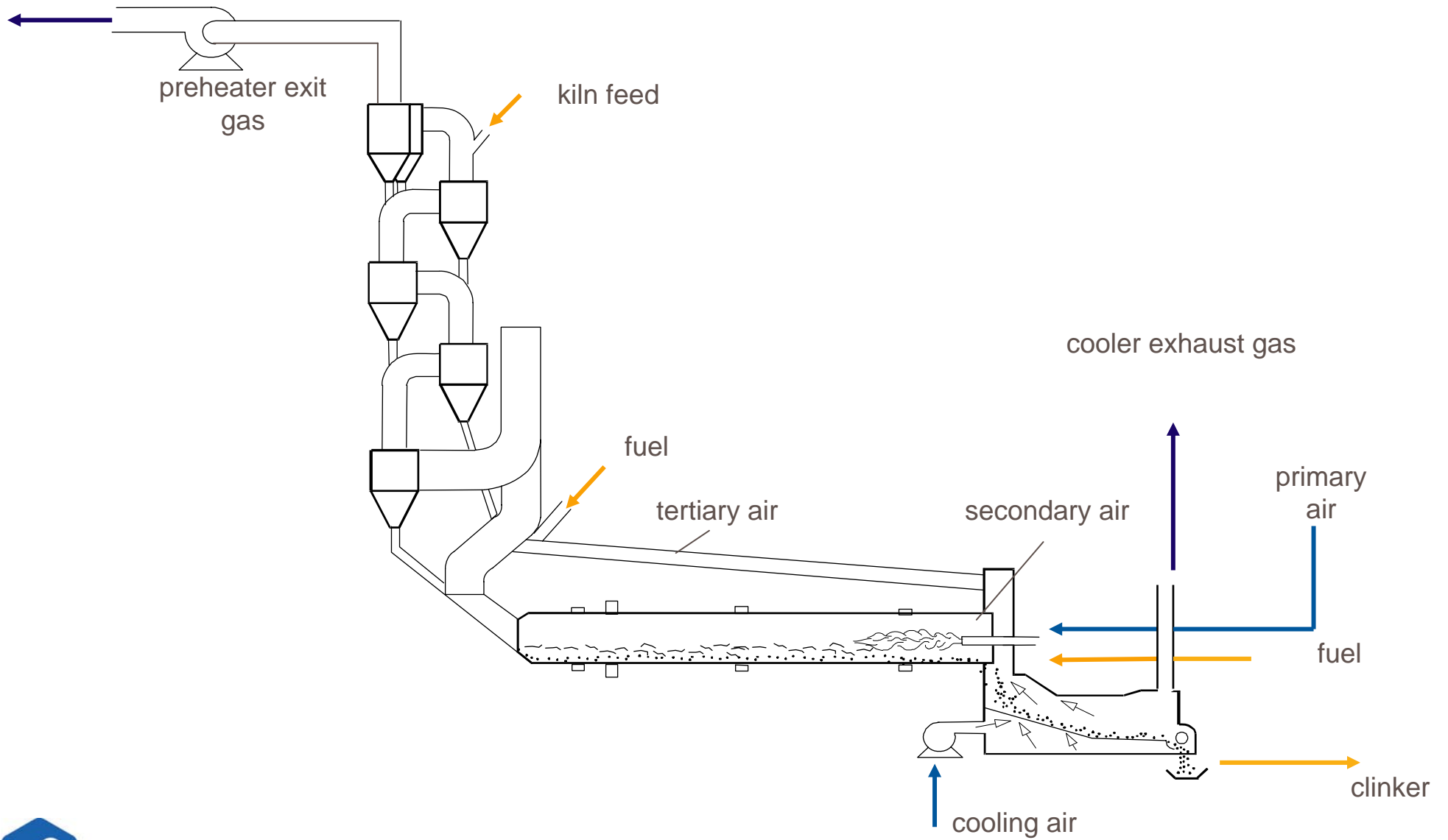
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Clinker burning process

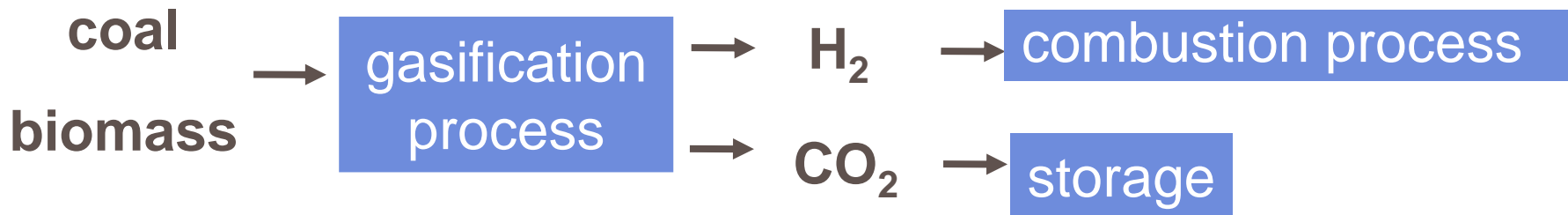
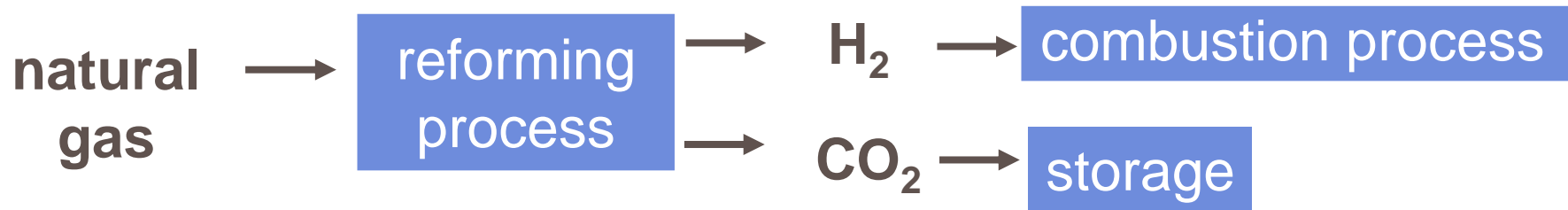


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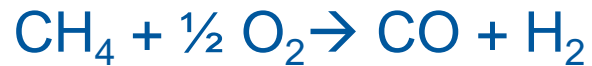


3.1 Pre-combustion technologies



Scheme of gasification process

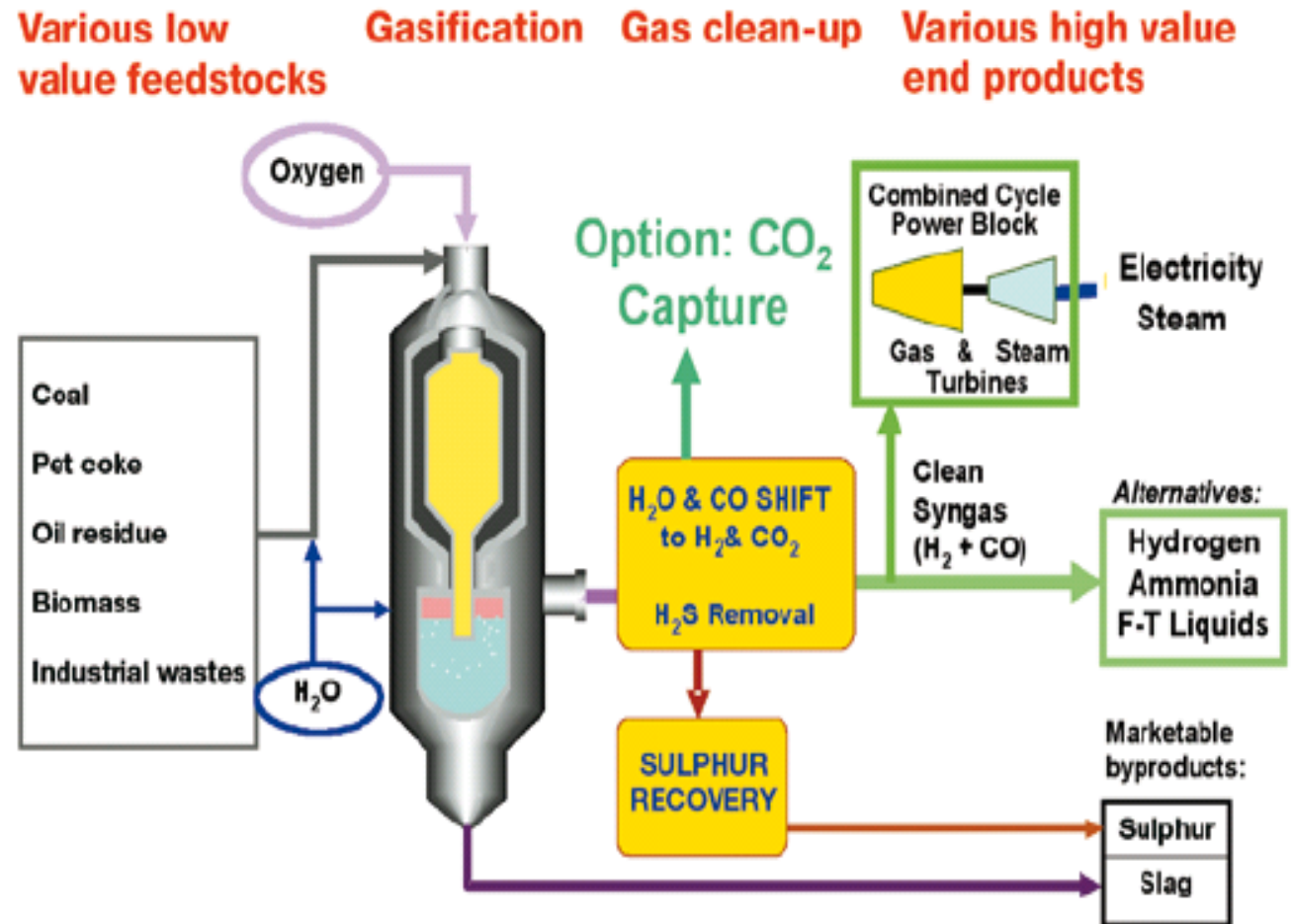
- Partial oxidation for heat supply



- Gasification of solid carbonaceous matter



- CO shift for hydrogen synthesis



Pre-combustion technologies: level of implementation

- Steam reforming is the predominant technology for H₂ production worldwide
- IGCC (Integrated Gasification Combined Cycle) demonstration plants since the 1970s
- IGCC can be realized with or without CO₂ capture
- Today no IGCC plant with capture technology in operation
- Two IGCC projects planned with CO₂ capture:
 - Australia (100 MW)
 - Germany (450 MW)
- CO₂ capture costs for new IGCC plant: 13-37 \$/t CO₂ (CO₂ capture by physical absorption)

Gasification of coal and petcoke for power generation - Puertollano IGCC Power Plant (Spain)



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Applicability of pre-combustion technologies to clinker burning process (1)

Hydrogen from syngas of gasification processes as fuel for cement kiln burners?

- Hydrogen has different properties as actual fuels:
 - handling/feeding must be solved
 - pure H₂ cannot be used in kiln firing
- H₂ flames have low heat transfer by radiation
 - temperature profile in the kiln
 - injection of raw meal or clinker dust



Applicability of pre-combustion technologies to clinker burning process (2)

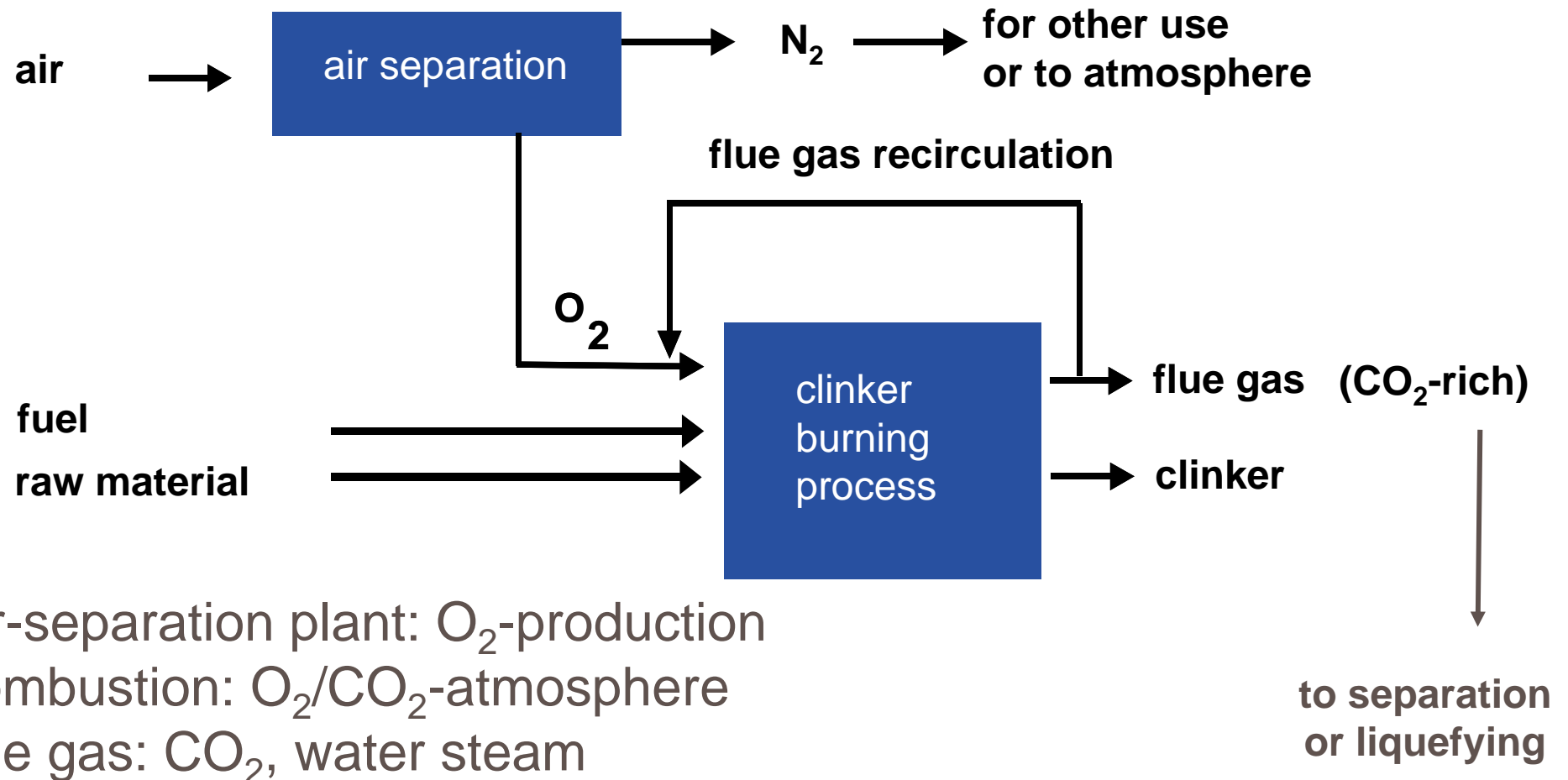
Hydrogen from syngas of gasification processes as fuel for cement kiln burners?

- New combustion technologies required:
 - non-carbonaceous flame ingredients
 - new burner technologies for increasing heat transfer
- Only abatement of fuel CO₂
 - only 1/3 of CO₂ emission is captured



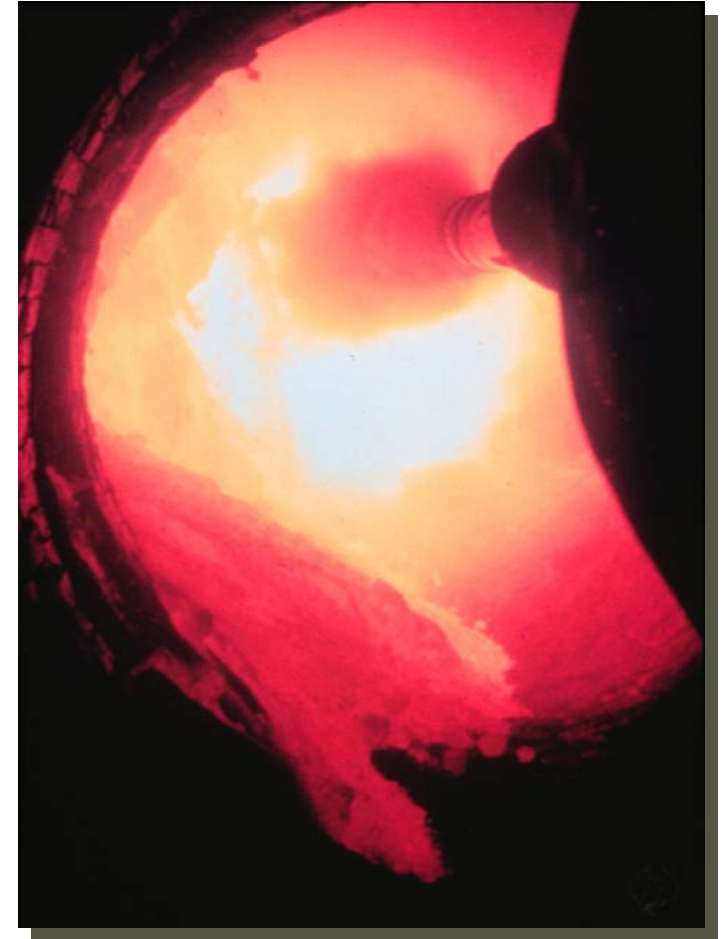
→ hardly promising for clinker burning process

3.2 Oxy-fuel Technology



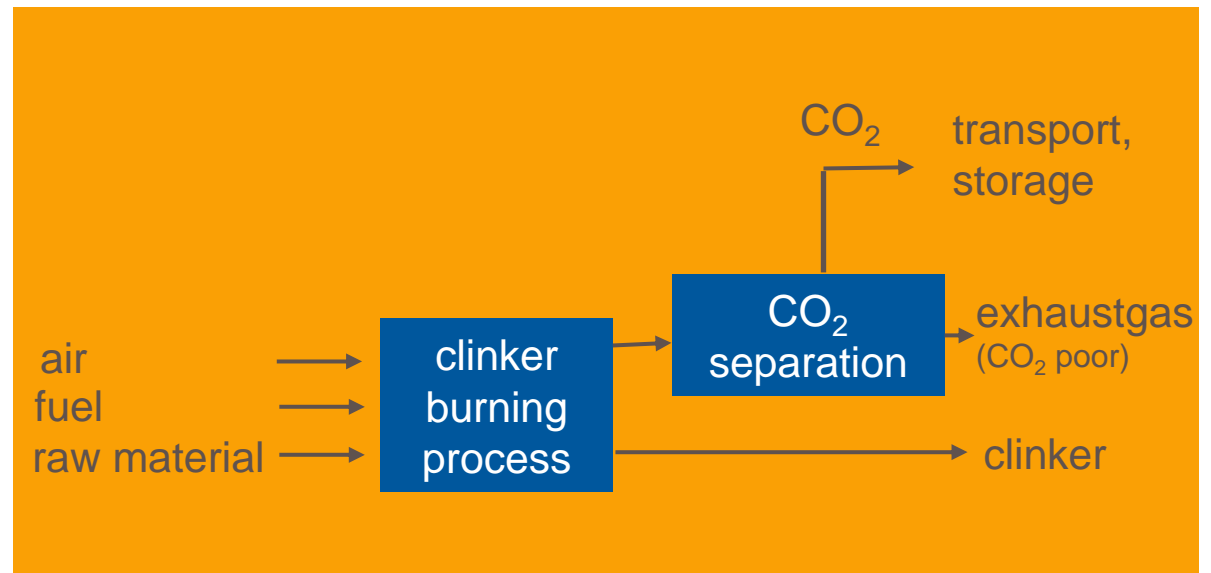
Applicability of oxy-fuel technology to clinker burning process

- Oxygen production by air separation is state of the art (by freezing or membranes)
- Oxy-fuel technology is state of the art in other industries, e.g. for glass production
- New combustion technologies required, e.g.:
 - Oxy-fuel burner
 - Waste gas recirculation
- Modifications of plant design, e.g.
 - Dimensions of kiln, cooler, preheater
 - Gas recirculation including dedusting, cooling
- Impact on reactions (e.g. decarbonation) and clinker quality



3.3 Post-combustion technologies

- Absorption technologies:
 - chemical absorption (Econamine[®]; Benfield[®], etc.)
 - physical absorption (Selexol[®], Rectisol[®], etc.)
- Membrane processes
- Solid sorbent processes
 - physisorption processes
 - mineral carbonation
 - carbonate looping



- the higher the CO₂ concentration the higher the capture efficiency
- end-of-pipe technologies; retrofit to existing plants possible



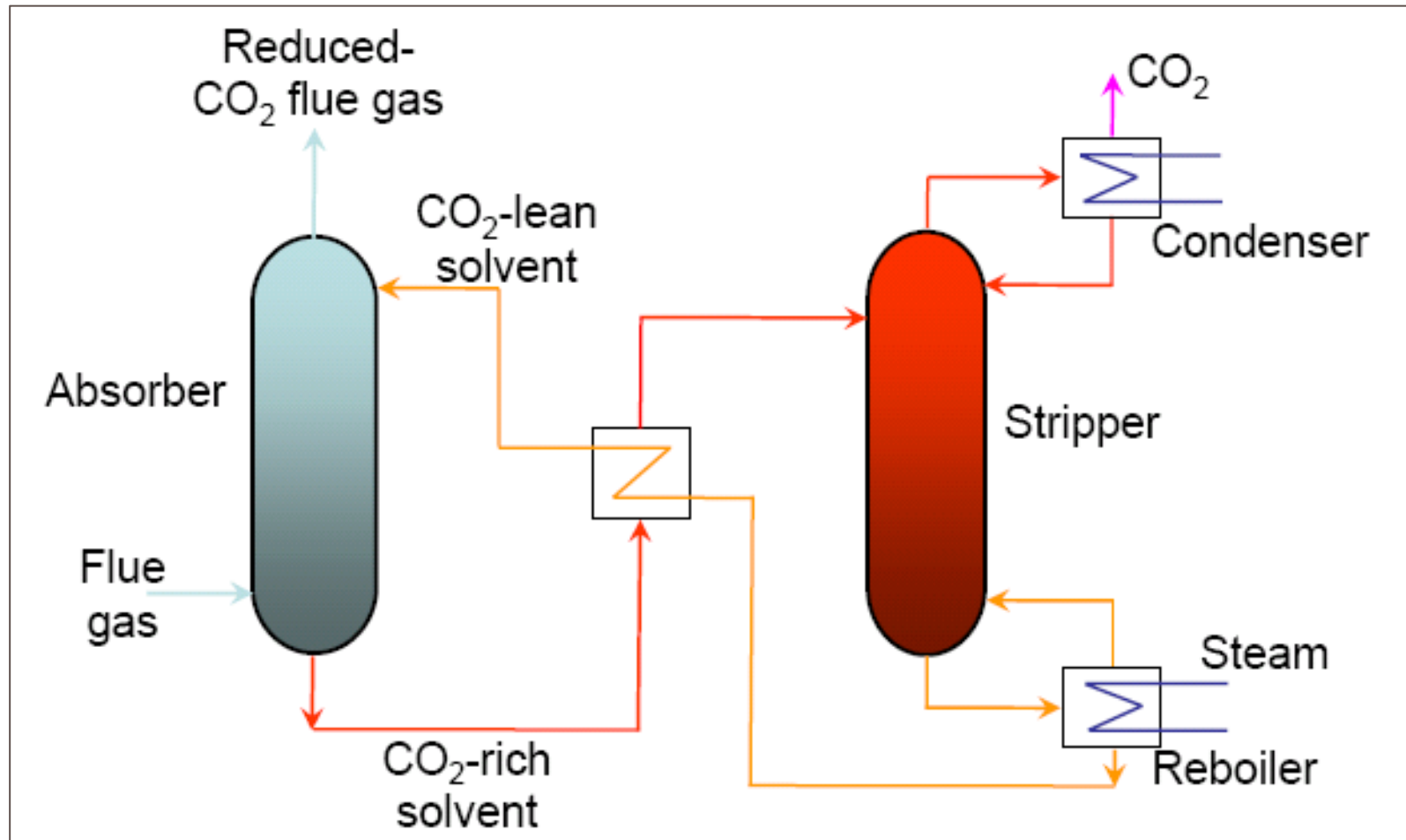
Absorption technologies are most developed today

- **Chemical absorption:**
 - amines (e.g. MEA) or inorganic salt solutions (e.g. K_2CO_3) as absorbent
 - high energy demand for solvent regeneration
 - very low dust, SO_2 and NO_2 concentration required
 - CO_2 capture costs for new coal-fired power plants: 29-51 \$/t CO_2
- **Physical absorption:**
 - solvents as absorbent (e.g. methanol)
 - high CO_2 content required



↑ CO_2 capture by chemical absorption
(fertilizer plant in Malaysia)

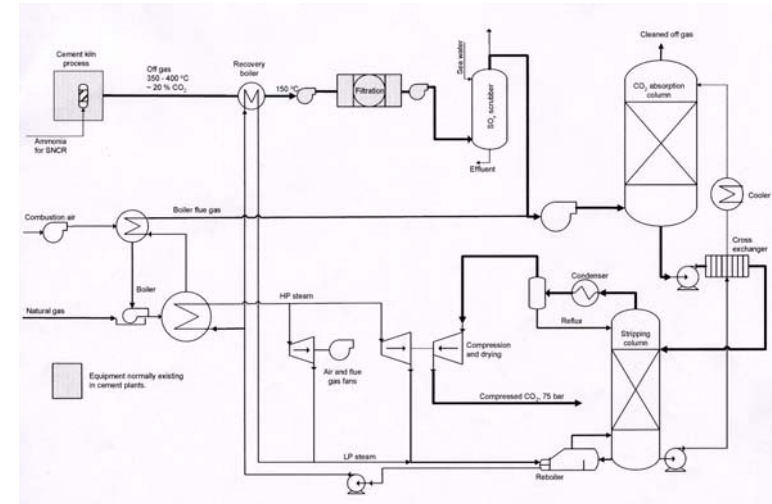
Simplified flow sheet of chemical absorption process for CO₂ capture



Application of CO₂ capture with amine absorption in a Norwegian 3000 t/d cement plant (pilot study)

Technical requirements

- NO_x abatement with SNCR
- SO₂ abatement with wet scrubber
- waste heat recovery boiler
- CO₂ capture amine absorption
- Amine recovery with stripper
- Gas fired boiler



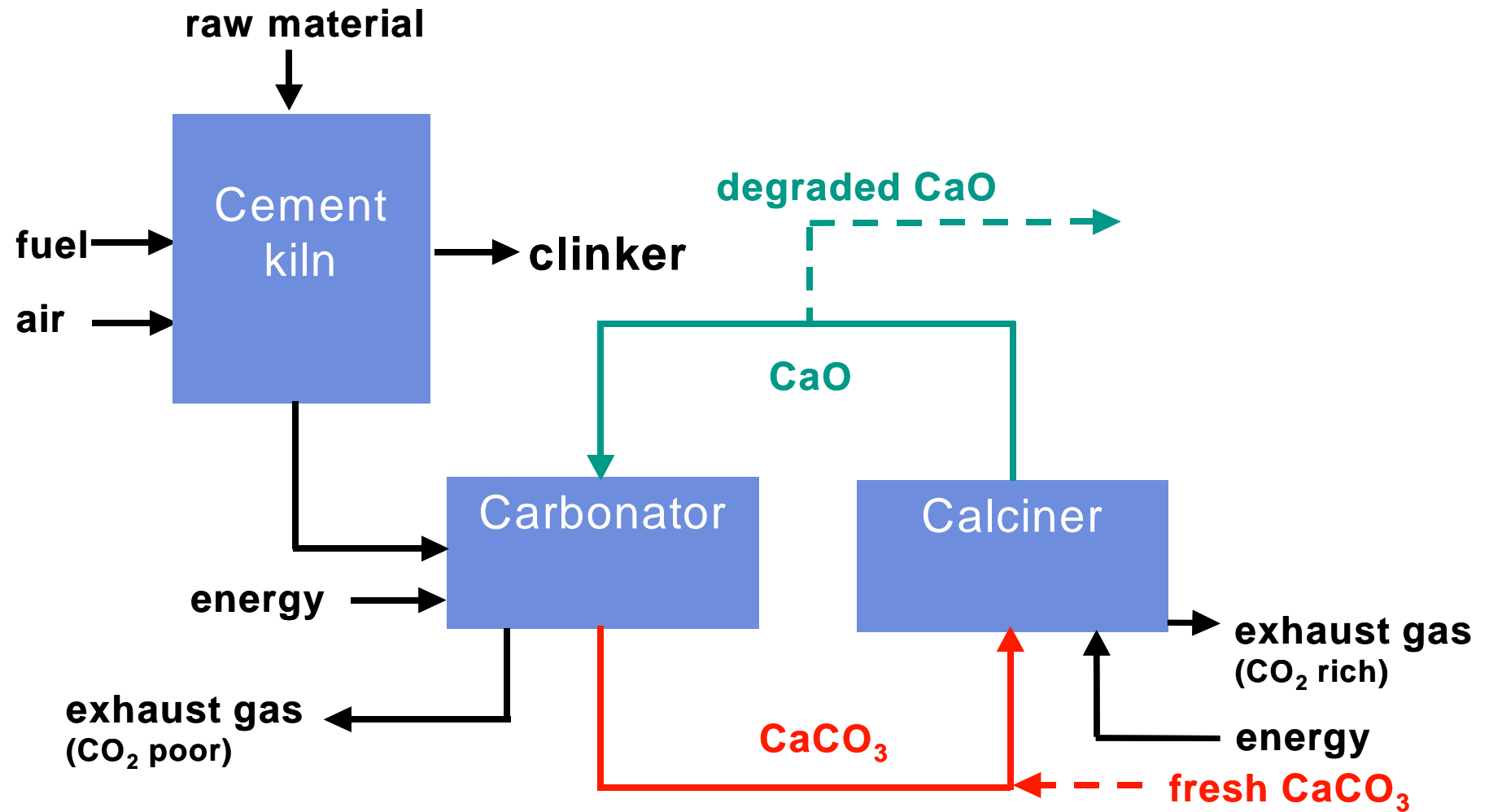
Investment costs in mio €	110
thereof:	
- waste gas cleaning	8
- waste heat recovery boiler	7
- CO ₂ capture	32
- CO ₂ drying and compression	28
- boiler	28
Operating costs in mio €/year	32
Total costs in €/t CO₂	45

2006 data

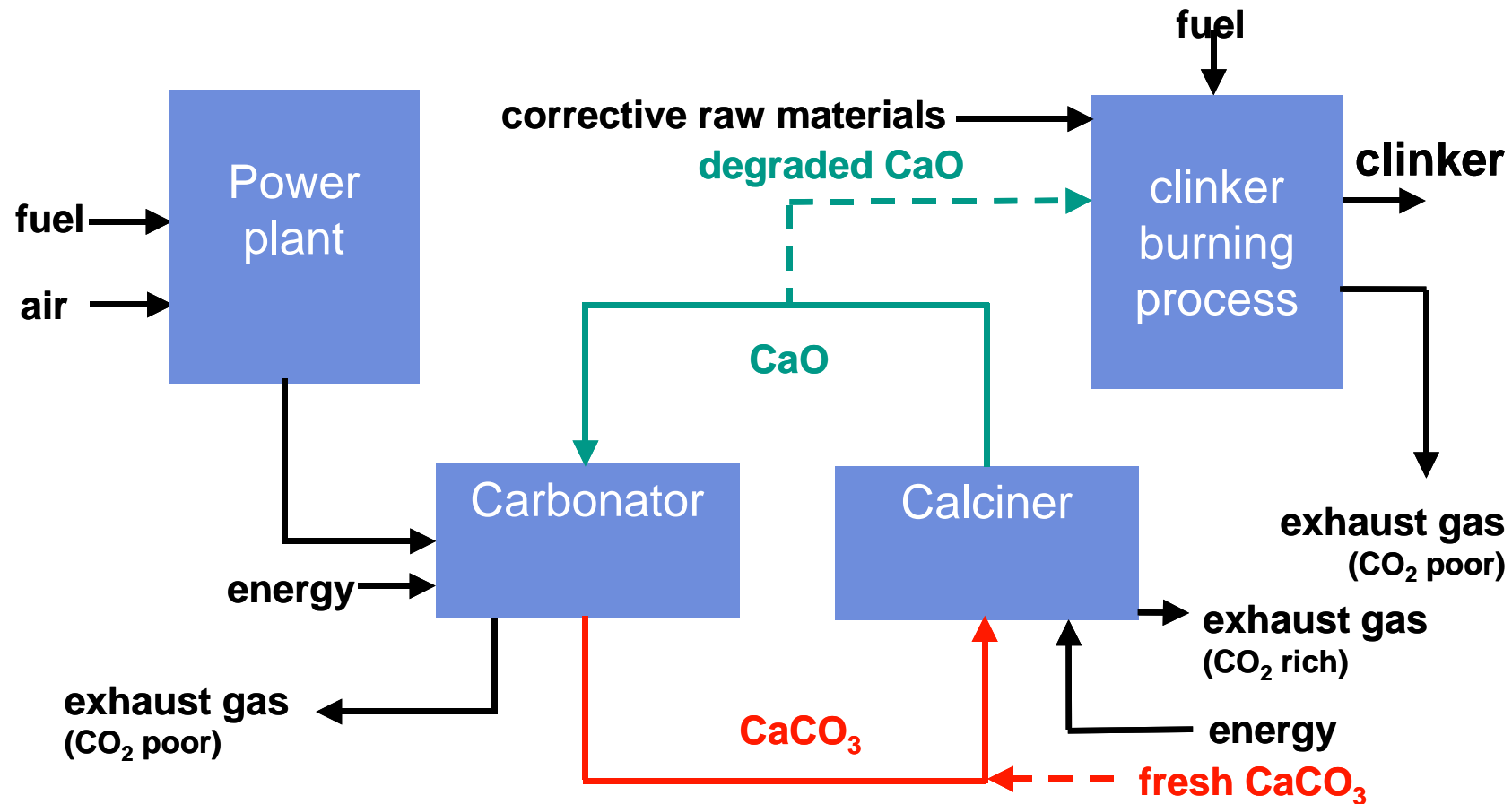


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Carbonate looping



Synergy of cement and power plants



One 3,000 tpd kiln utilizes degraded sorbent (after 30 loops) of three 800 MW_{el.} power plants.



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Assessment of CO₂ capture technologies

capture technology	availability on scale			applicability in the cement industry	reduction of
	research	demo	industrial		
Pre-Combustion - reforming / gasification	X	X	X	yes (new kilns)	only fuel CO ₂
Oxyfuel	X		(X)	yes (new kilns)	fuel and process CO ₂
Post-Combustion - absorption	X	X	X	yes (process re-design)	fuel and process CO ₂
- membranes	X		(X)	?	fuel and process CO ₂
- solid sorption process	X		(X)	?	fuel and process CO ₂
Hybrid Systems - solar cement plant	X			“Yes but” (new kilns)	only fuel CO ₂
- carbonate looping (cement / power plant)	X			yes (one-field application)	fuel and process CO ₂

Potential future application of CCS in the cement industry

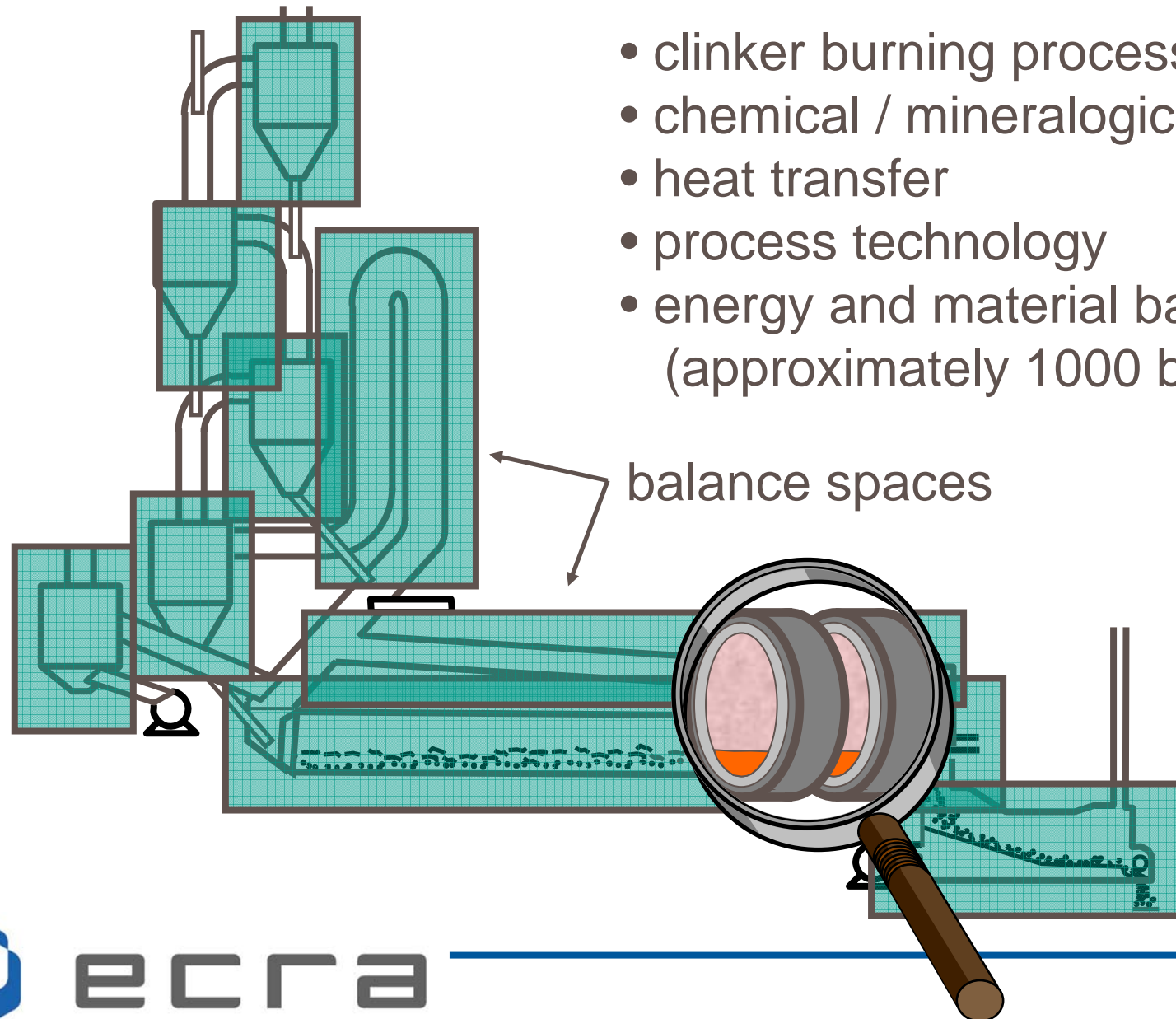
- Short-term: no relevance due to
 - very high costs (> 50 \$/t CO₂ avoided)
 - not existing availability of capture technologies
- Medium-term: depends on policy decisions and technical developments
 - climate policy (incl. USA, China, India)
 - cost reductions due to technical developments (target value: 20-30 \$/t CO₂)
- Long-term: high relevance possible if
 - other options are exhausted
 - worldwide comparable costs for cement production would be introduced

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Modeling of the clinker burning process



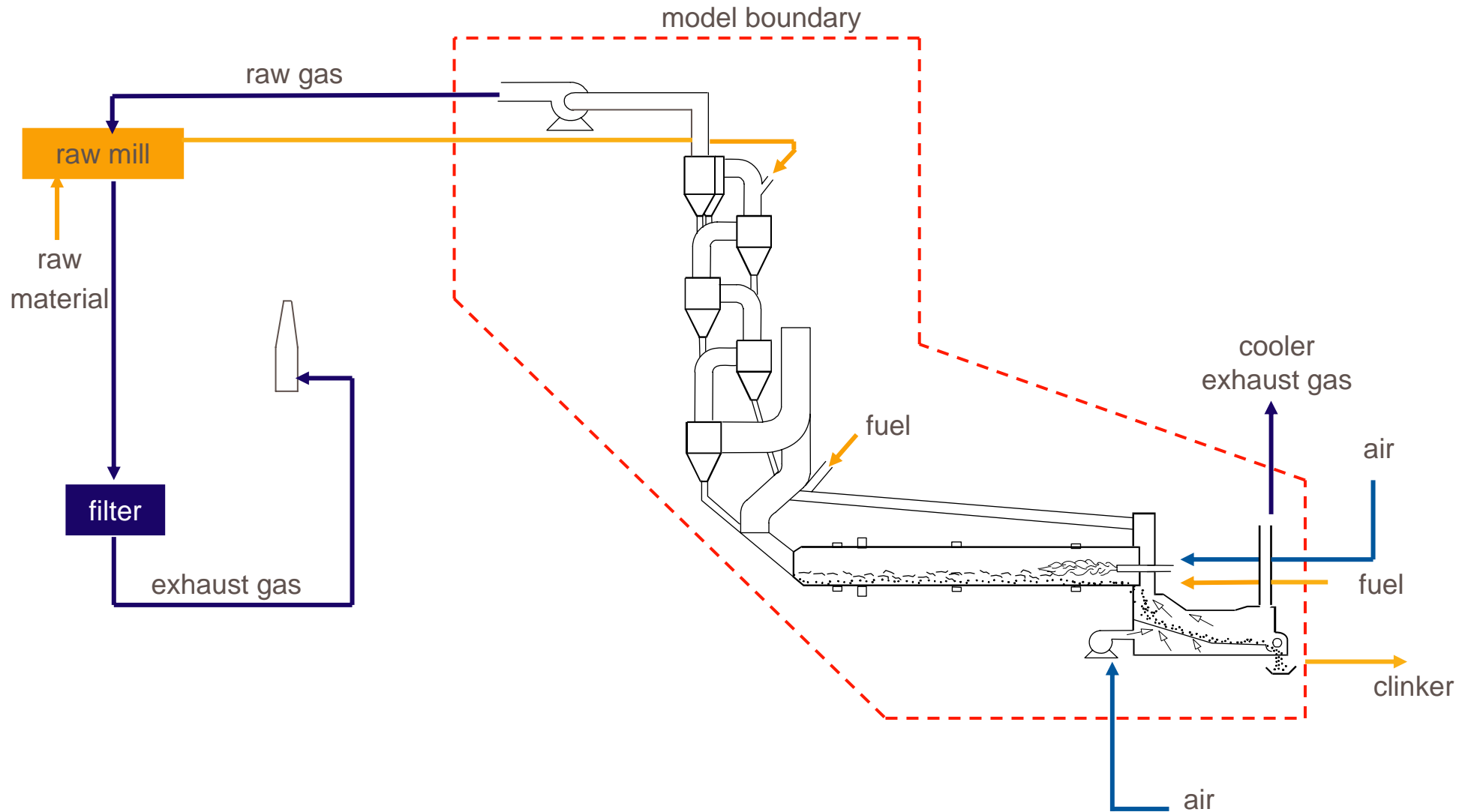
- clinker burning process (dry)
- chemical / mineralogical reactions
- heat transfer
- process technology
- energy and material balances
(approximately 1000 balance spaces)

balance spaces

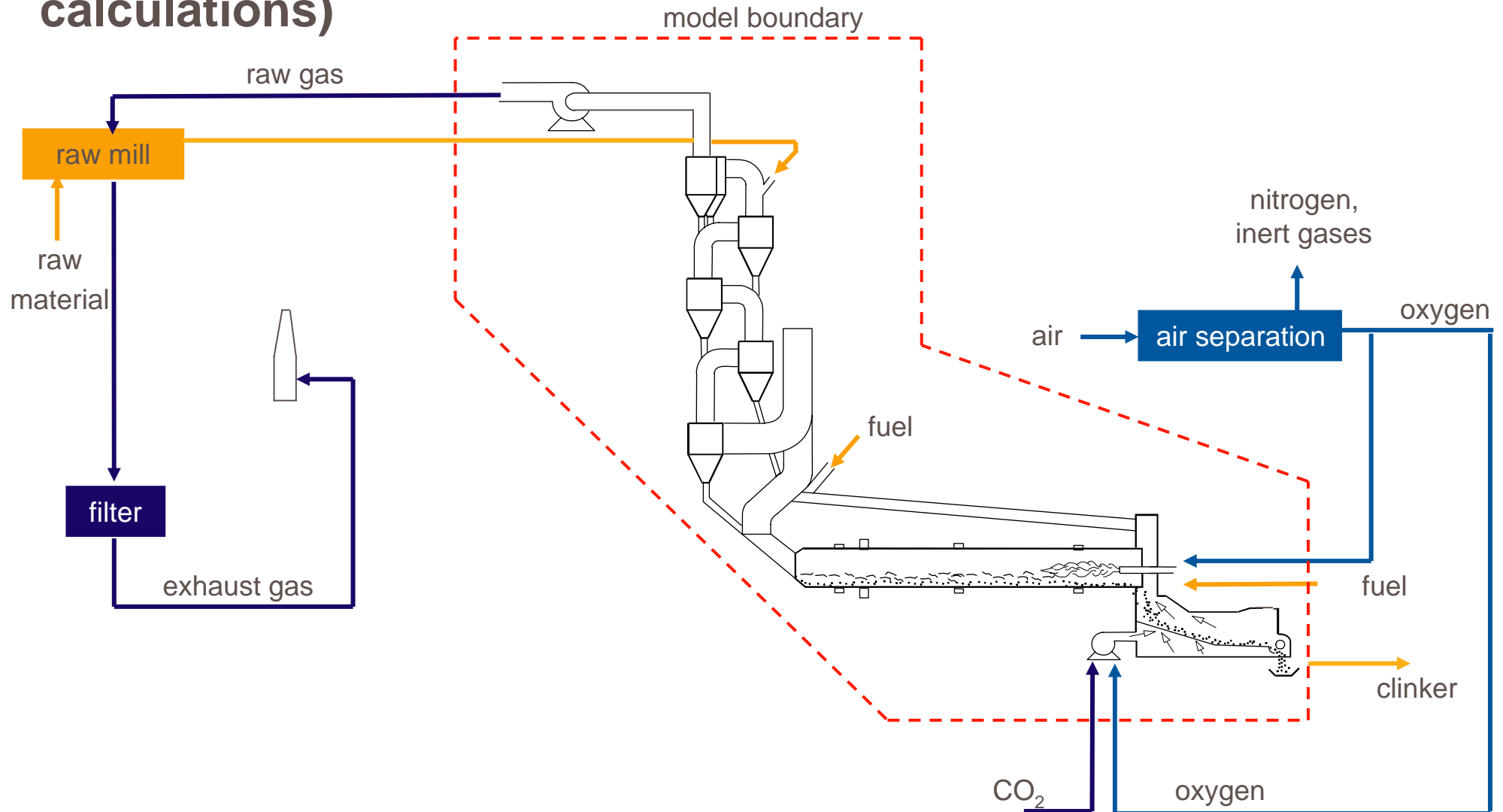


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Schematic diagram of the clinker burning process (reference)



Schematic diagram of the clinker burning process with oxyfuel operation (based upon assumptions for the simulation calculations)



Summary and outlook

- CO₂ capture technologies are not technically available for the cement industry
- Pre-combustion technologies are not promising because only fuel CO₂ would be captured
- Oxy-fuel technology is state-of-the-art in a few other industry sectors and seems to be promising for new kilns
- Post-combustion technologies are state-of-the-art in other industry sectors, but on relatively small scale
- From a today's point of view CCS is by far too expensive for the cement industry
- Huge research efforts would be/are necessary to develop CO₂ capture technologies for the cement production process

Ecra research project shall enable the cement industry to give scientifically based reliable answers to political requirements in the future



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