Energy Systems
and Technology
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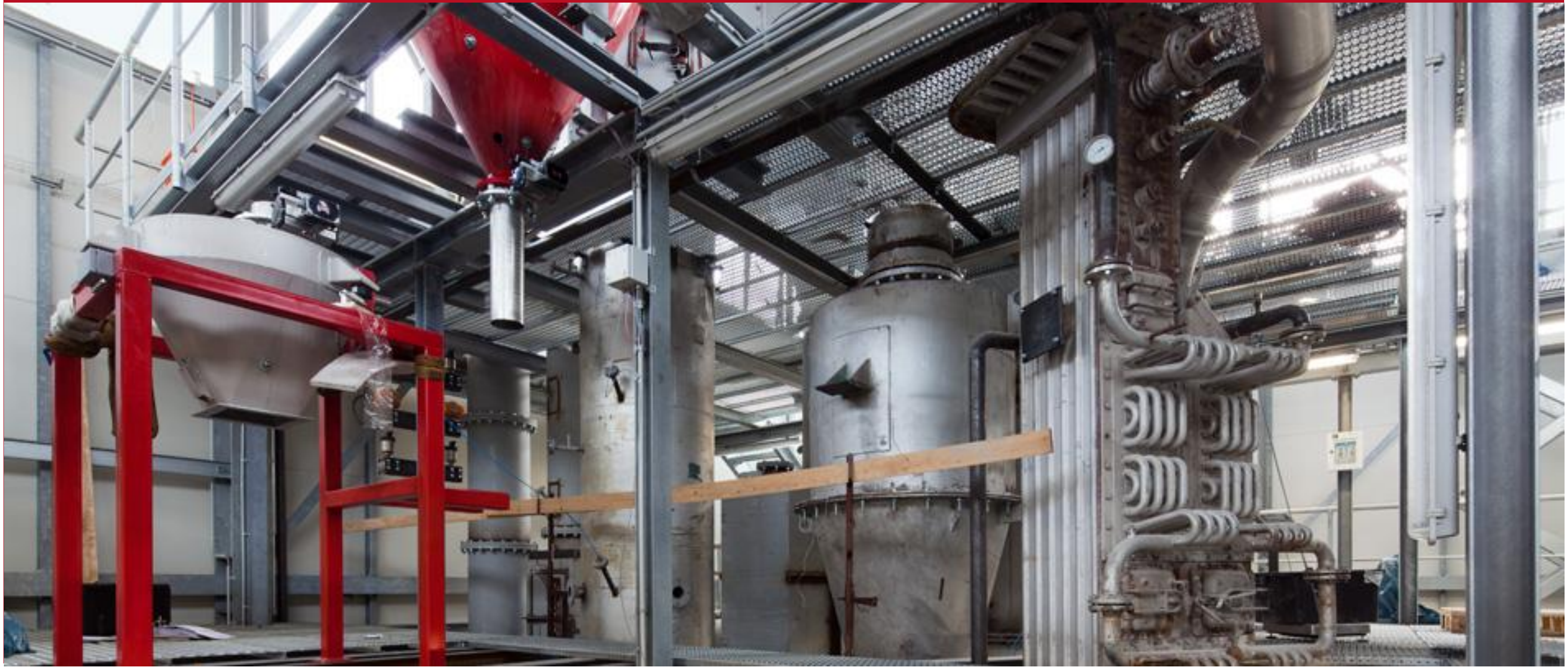
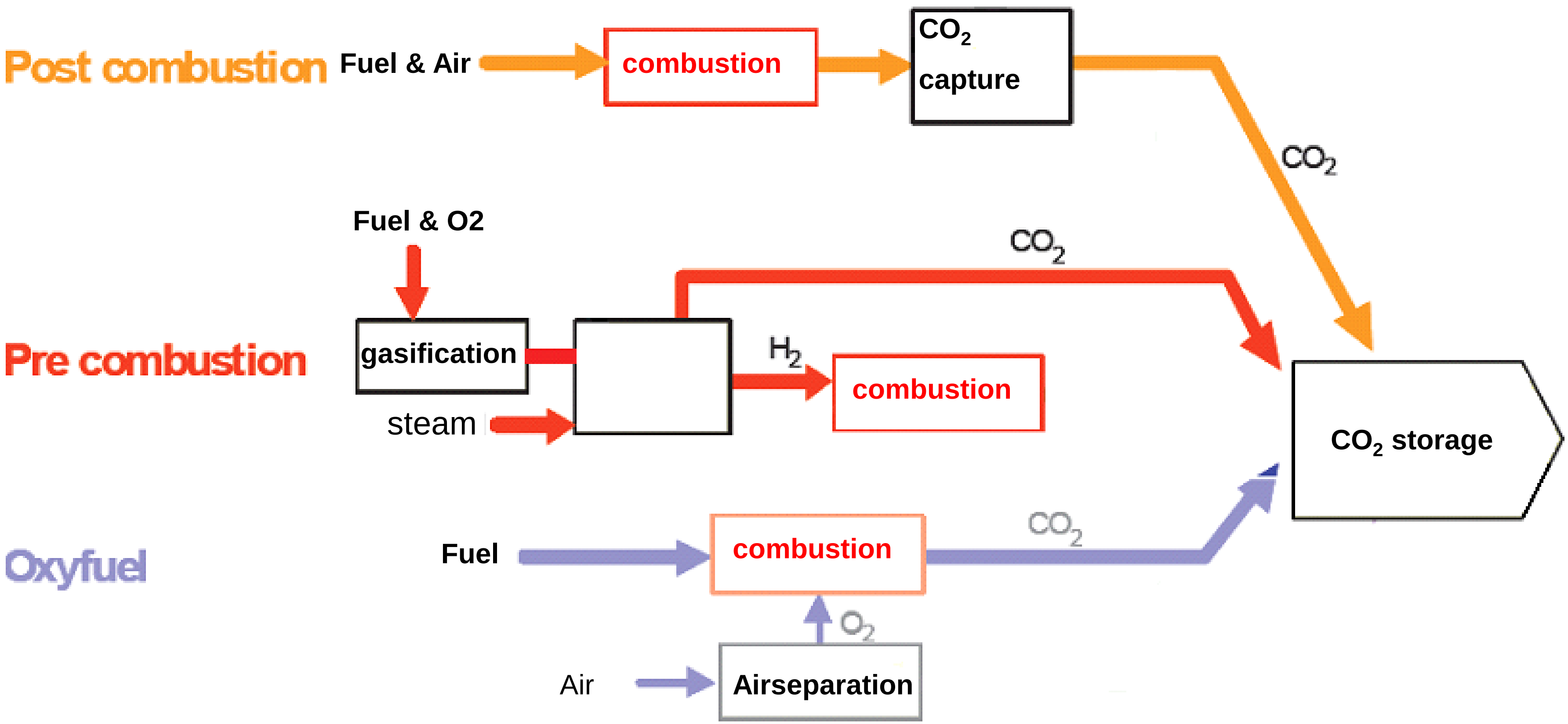
TECHNISCHE UNIVERSITÄT DARMSTADT

CO_2 Abscheidung bei Kohlekraftwerken mittels Chemical- und Carbonate Looping Verfahren

10. Mai 2012 Material Valley



Possibilities of Carbon Capture



Post Combustion Technologies

Amine Scrubbing

- high cost
- spent sorbents -> environmental
- efficiency loss ($\Delta\eta$ >10% - units)

+ several references

CO_2 mitigation costs > 45 EUR/ t CO_2

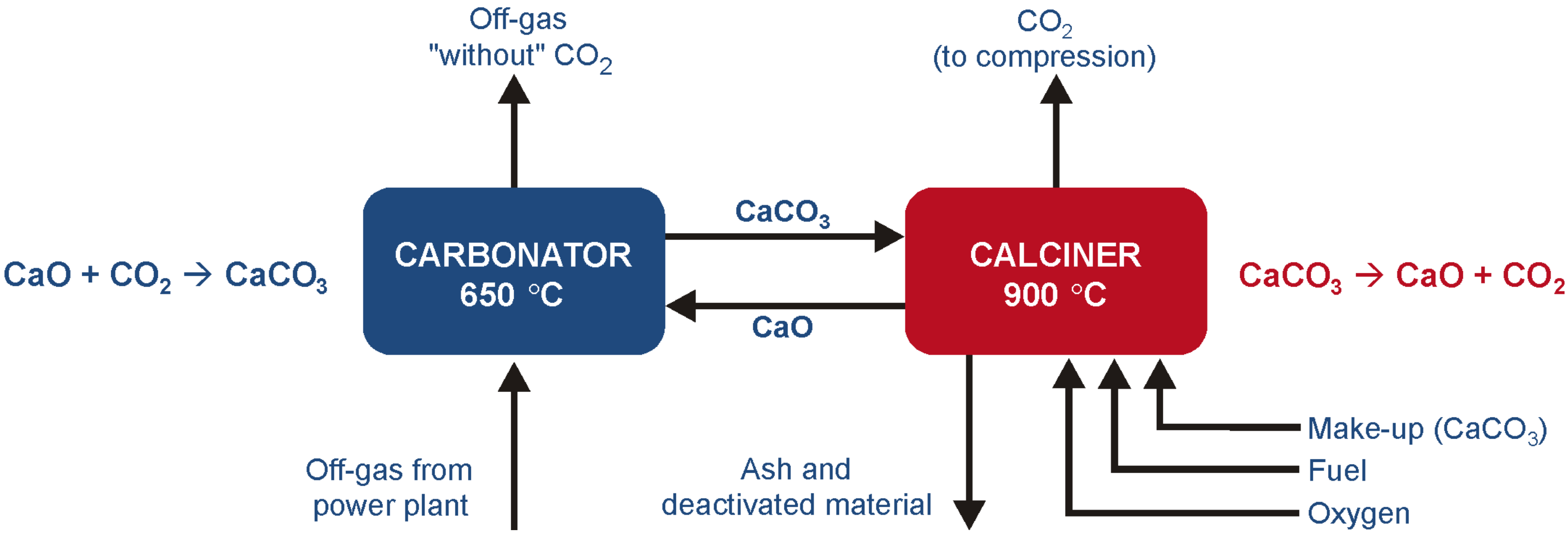
-> Alternative: **Carbonate Looping**

Eff. loss CO_2 capture: $\Delta\eta$ < 3 % - units (w/o compr.)
CO_2-compression: $\Delta\eta$ ~ 3 %- units
Total $\Delta\eta$ ~ 6 % - units
CO_2 mitigation costs ~ 20 EUR/ t CO_2

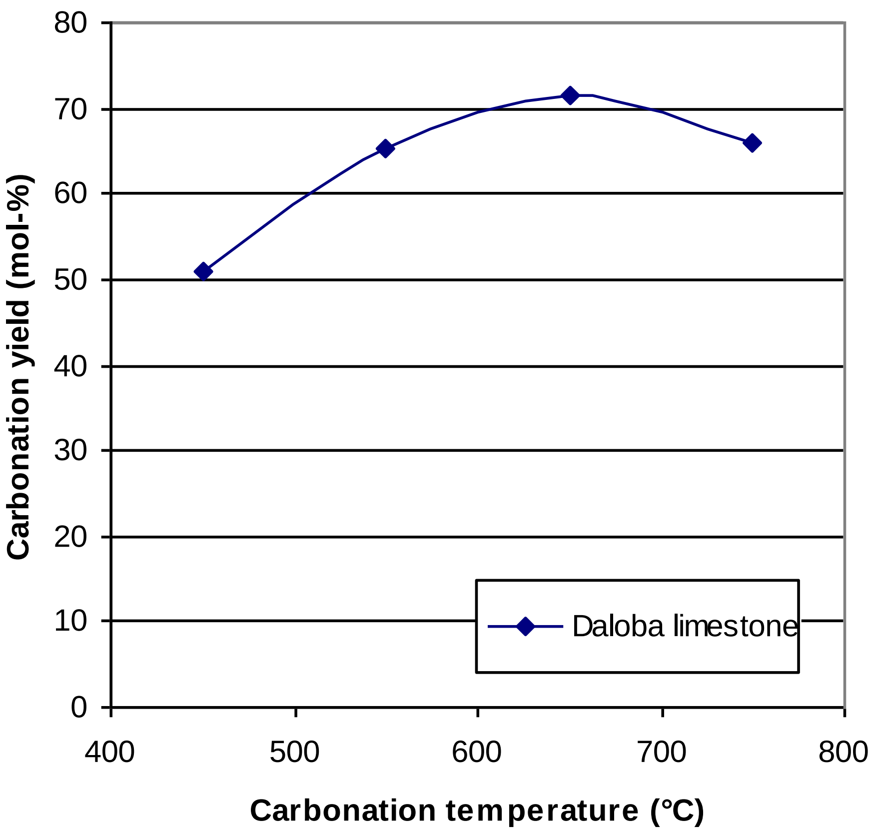
COORETEC Project LISA

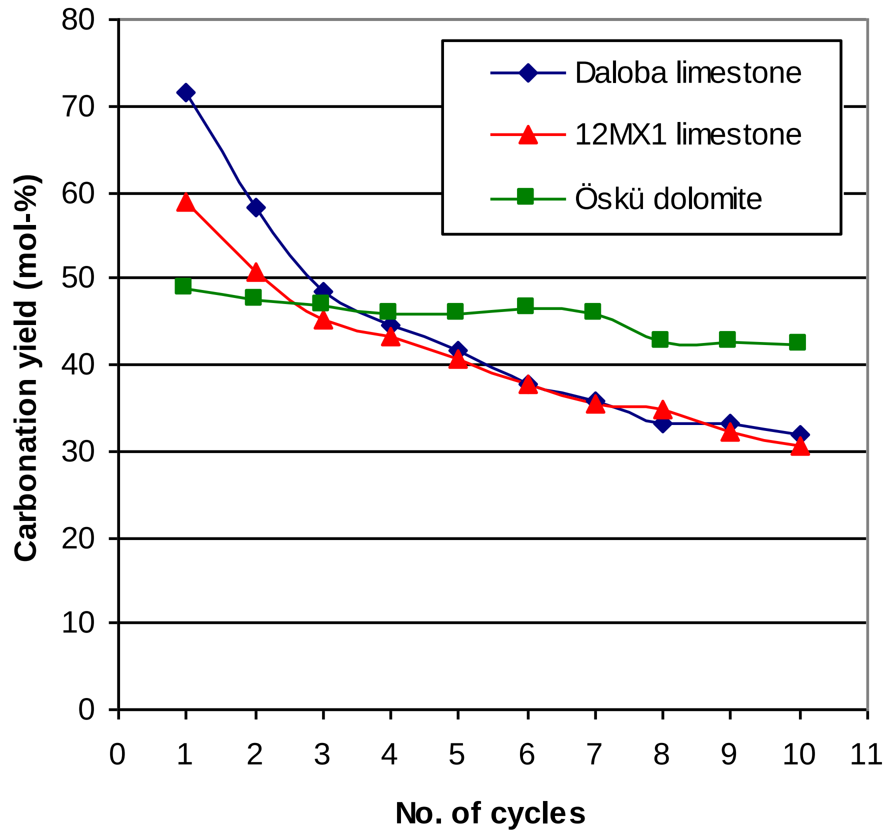
LISA - **Li**mestone ba**s**ed **A**bsorption of CO_2

Category: Post Combustion CO_2 Capture
Carbonate Looping



Results of Experiments Laboratory Testing

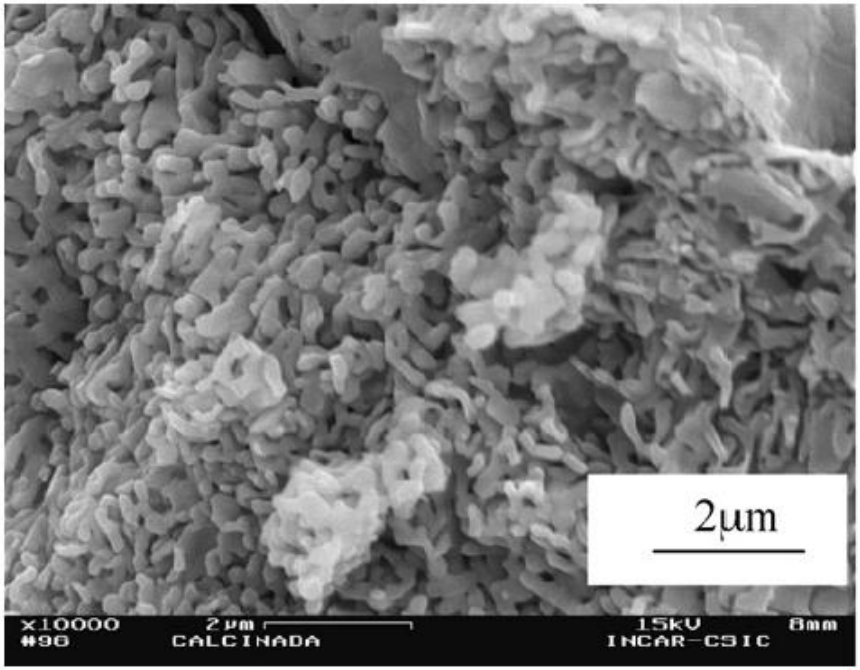




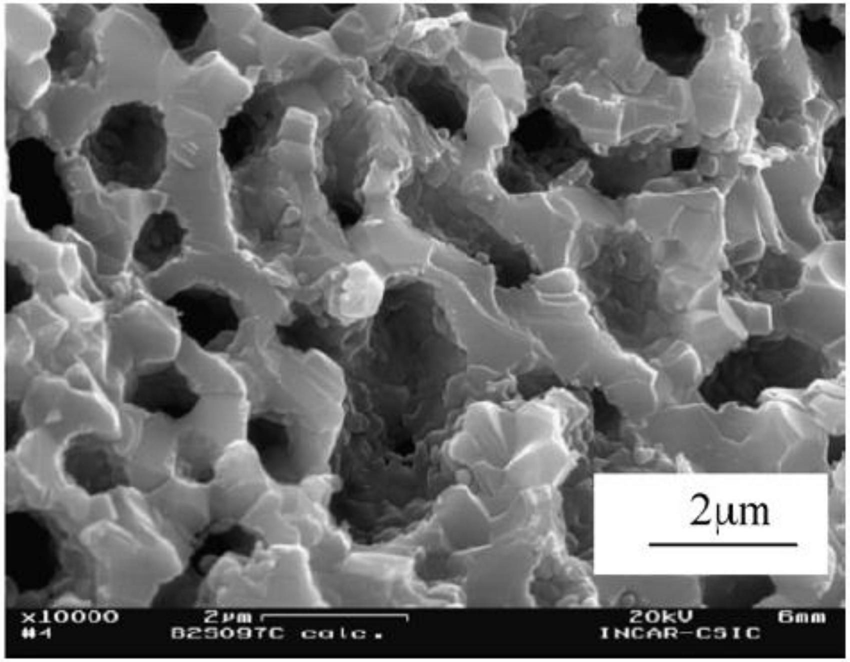
Source: Epple TU Darmstadt

CaO Particle Surface

Surface structure after cyclic carbonisation/calcination (Grasa et al., 2008)



After 1st cycle

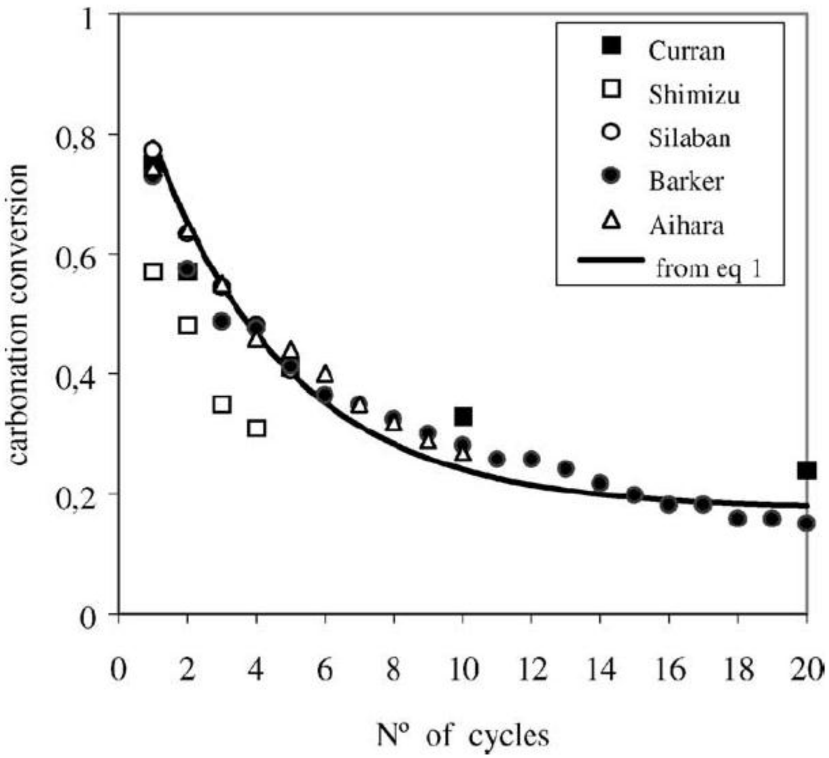


After 30th cycle

Enlargement of pores:

- Smaller reactive surface for CO_2 absorption
- Improved pore diffusion for SO_2 absorption

Carbonate Looping: Reaktivity of CaO



- Experiments in batch reactor with cyclic carbonisation/calcination (Abanades, 2002)
- Decrease of reactivity of CaO with number of cycles
- Reactivity converges against constant values of 15-20 %

- Application to continuous operation of two reactors

Scheme for Retrofit of an Existing Power Plant

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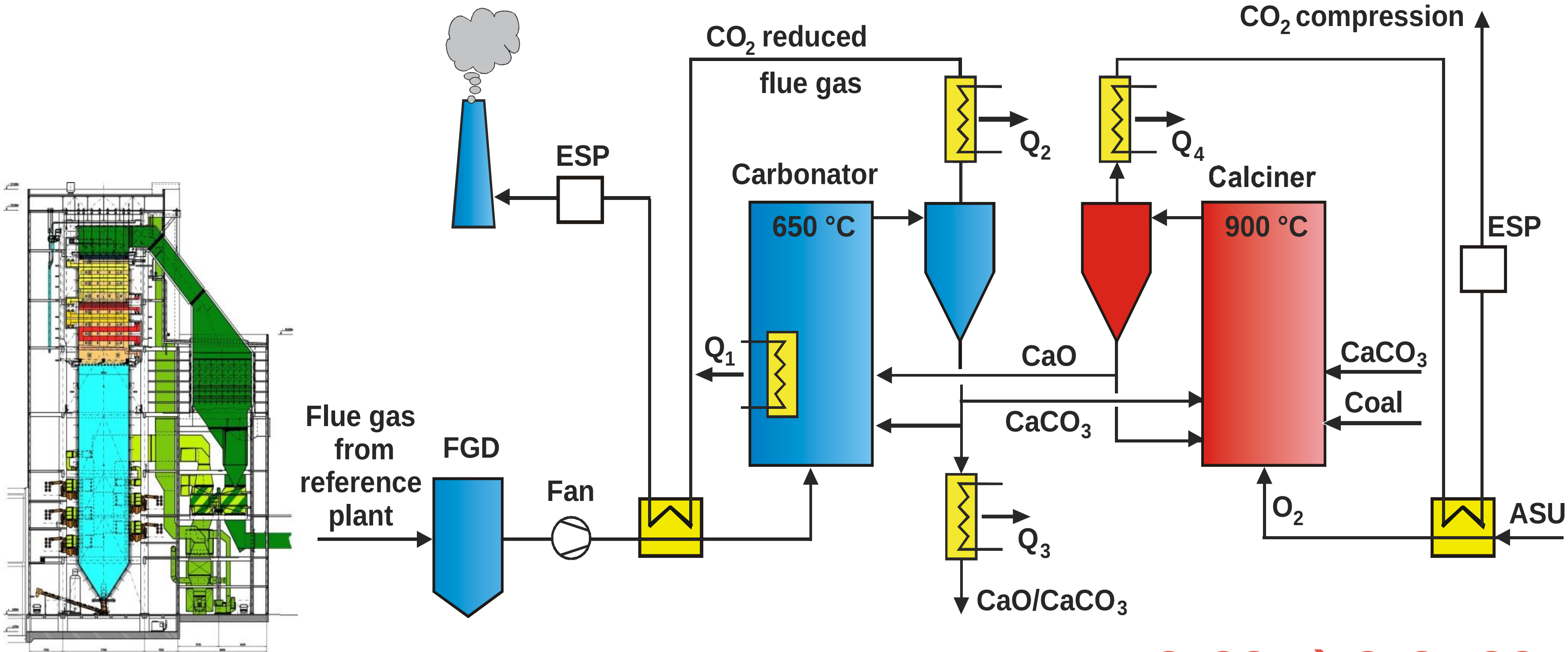


CO_2 capture by CaO

$CaO + CO_2 \rightarrow CaCO_3$

$CaCO_3 \rightarrow CaO + CO_2$

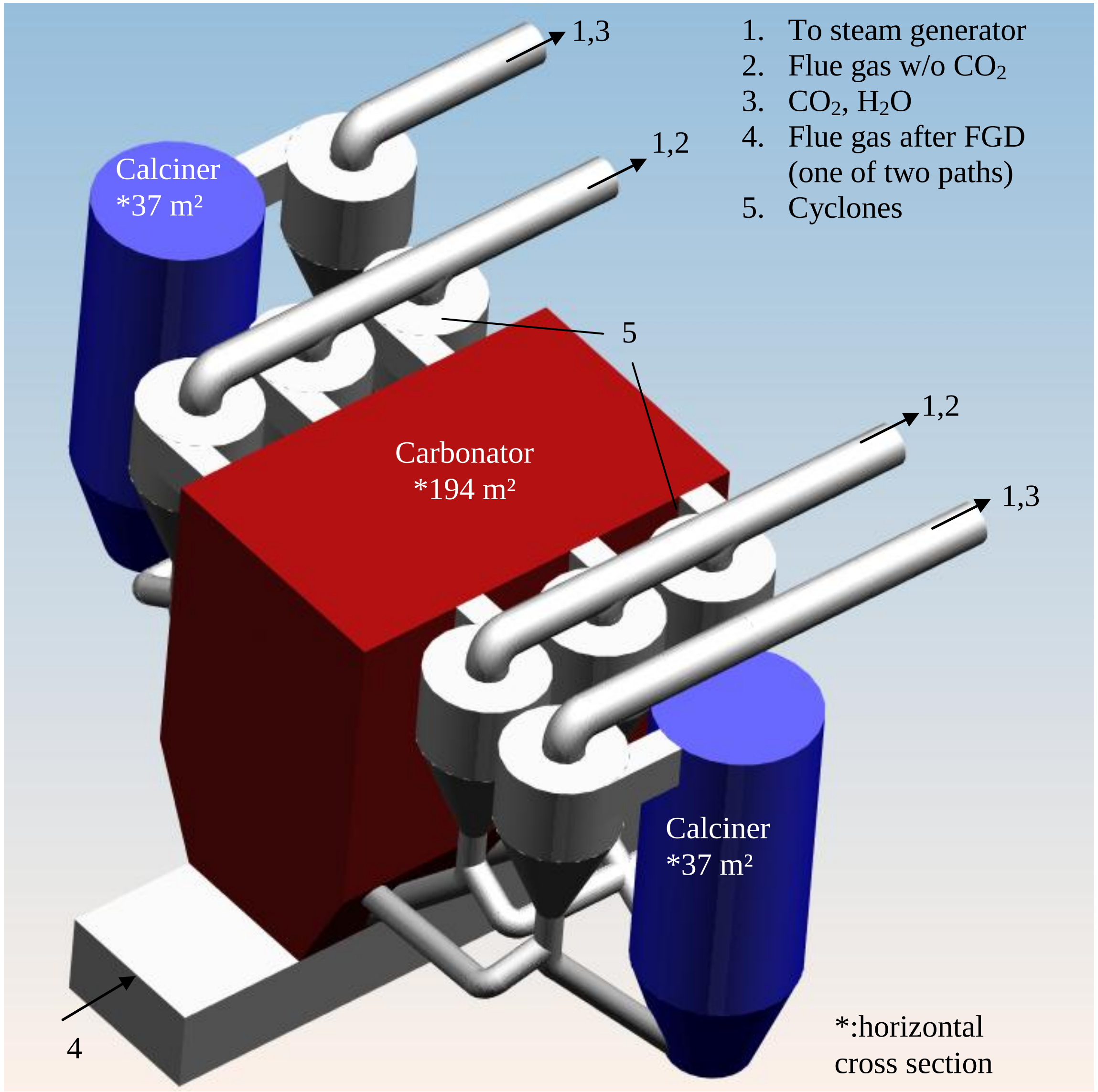
Reference plant: 1052 MW_{el} hard coal-fired power plant

Net efficiency of reference plant: 45.6 %

-> Basis for a FEASIBILILY STUDY

Sketch of a Carbonate Looping Unit

Carbonate looping unit for one flue gas cleaning train (of in total two parallel trains) for post-combustion CO_2 capture of 1052 MW_{el} hard coal fired plant.



Source: TU Darmstadt

Acknowledgements

COORETEC **Project LISA**
Lime**s**tone based **A**bsorption of CO2

COORETEC is an initiative by the Federal Ministry of Economics and Technology (BMWi) for the development of a power plant fired by fossil fuels with prospects for the future.

COORETEC means **CO2 re**duction **tec**hnologies

Erection of the Building 2009

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DARMSTADT

February

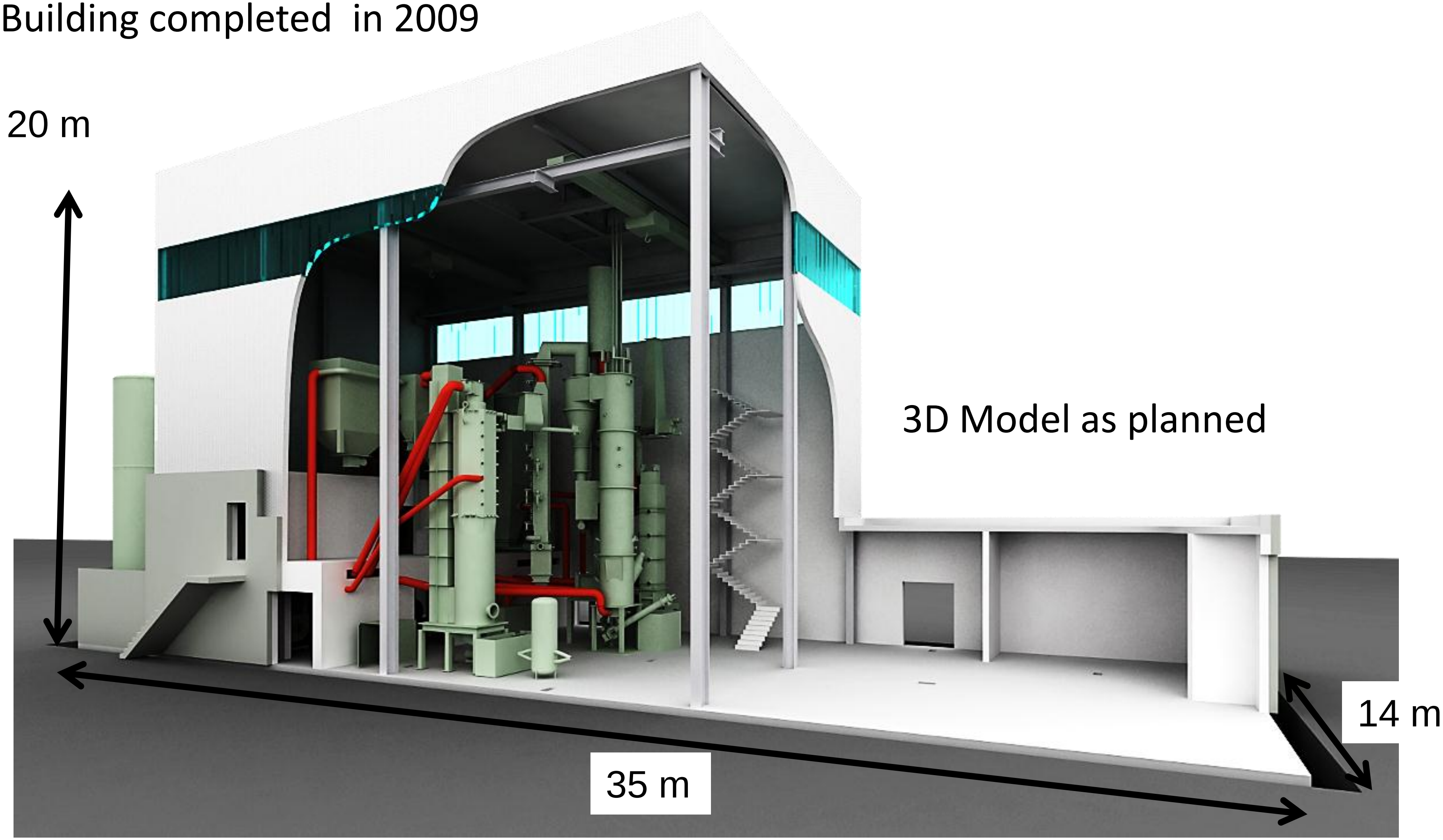
July

May

September

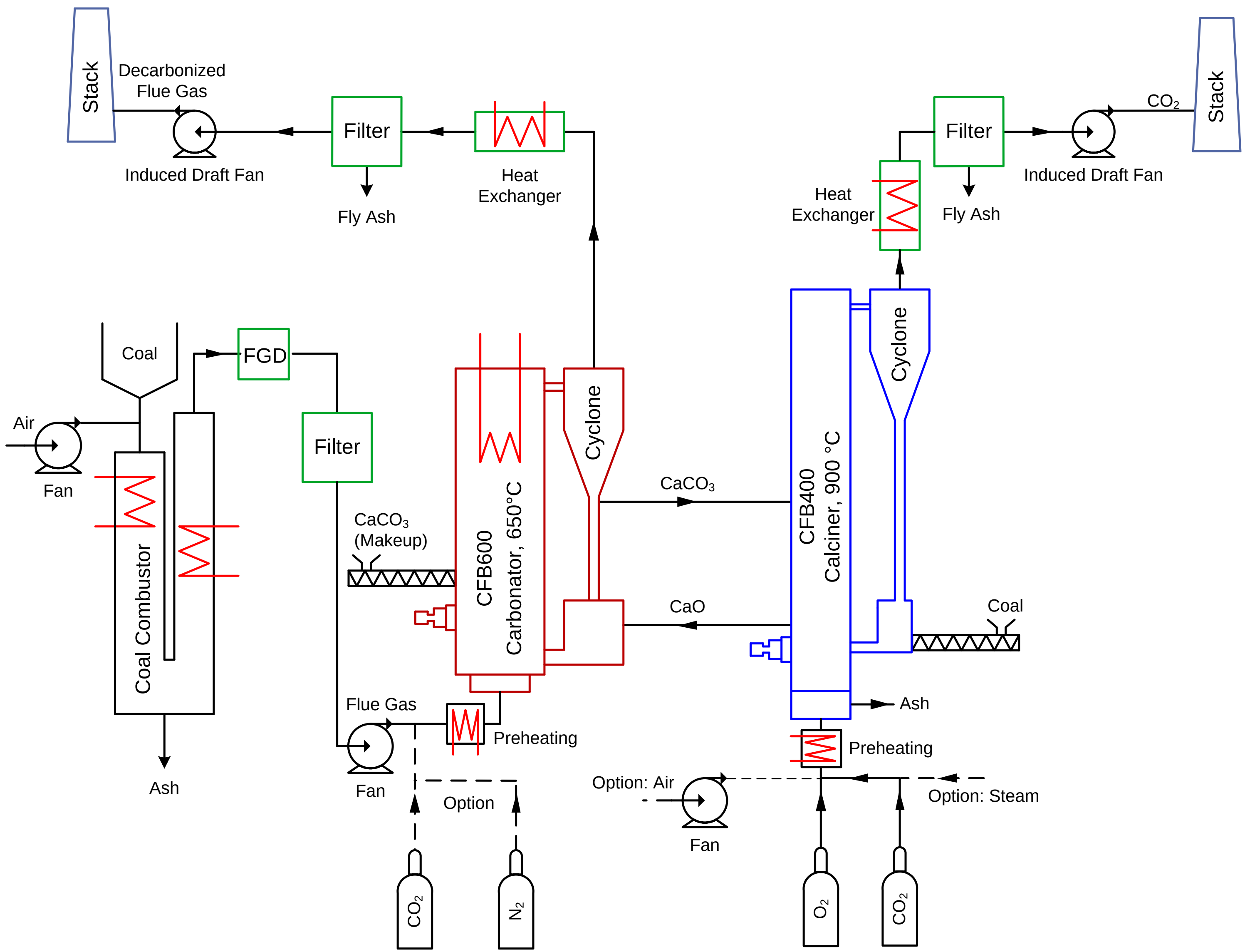
Laboratory with 1 MW_{th} Plant

Building completed in 2009



3D Model as planned

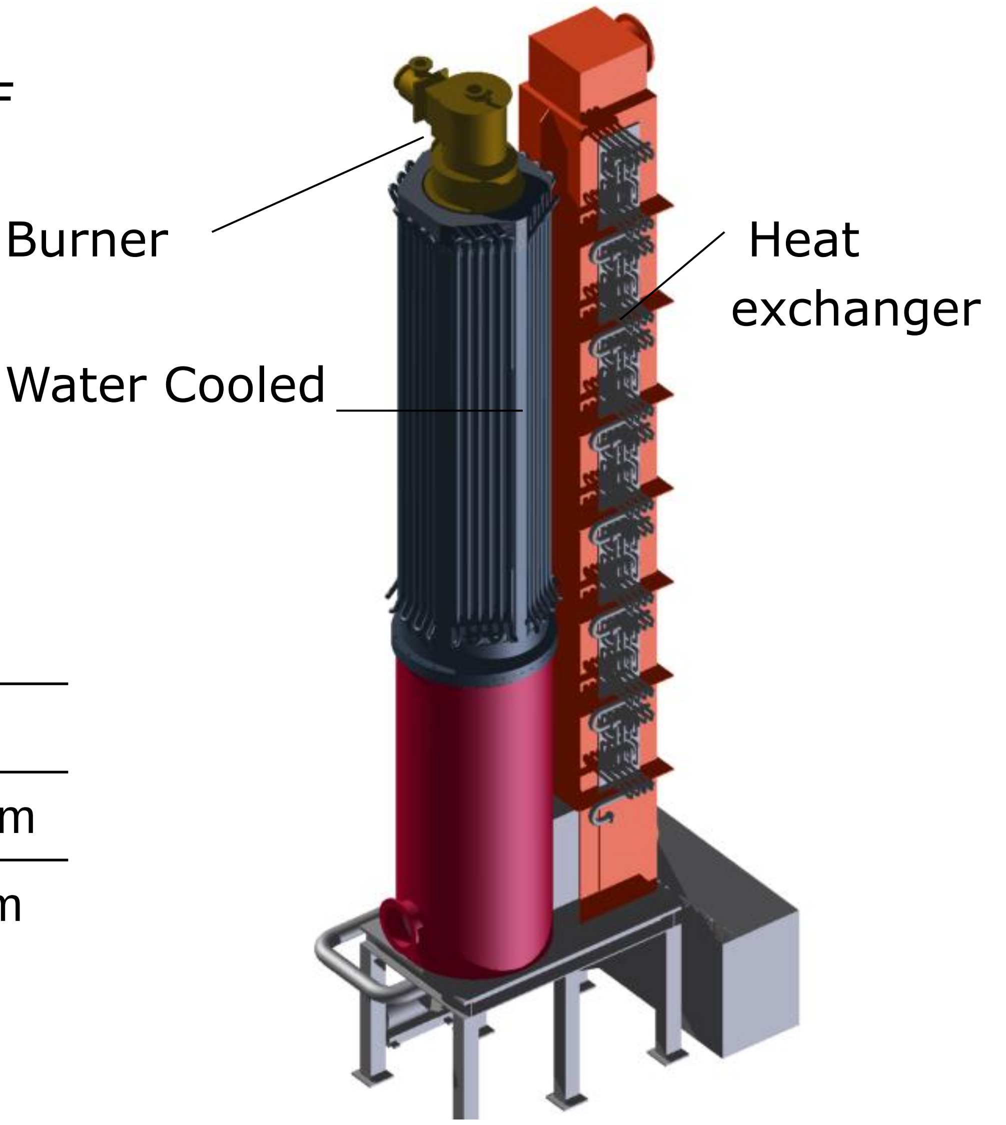
Carbonate looping configuration



Combustion Chamber 1MW

Combustion of Coal, Biomass, RDF

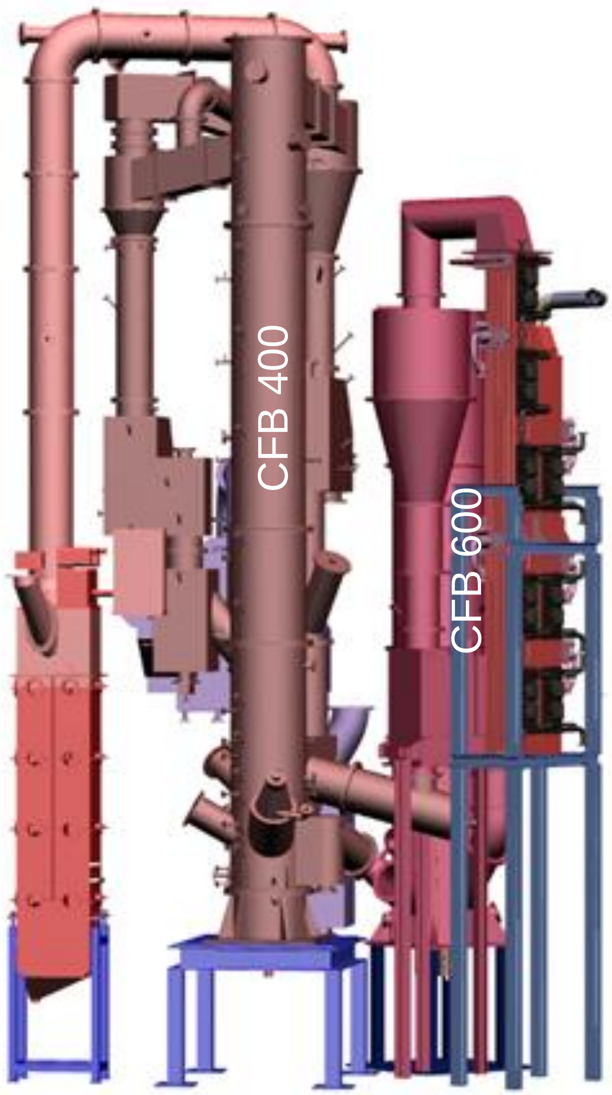
Function: Flue Gas Source
for Capture Capture



Technical Data Combustion Chamber

Thermal Load	1 MW
Height	7 m
Outer diameter	1300 mm
Inner diameter	750 mm

Technical data of CFB reactors



	CFB 600	CFB 400
Inner diameter of CFB	600 mm	400 mm
Outer diameter of CFB (refractory lined)	1300 mm	1000 mm
Height of CFB	8.66 m	11.35 m
Carbonate looping	Carbonator	Calciner
Chemical looping	Air reactor	Fuel reactor

CFB reactors of 1 MW_{th} plant

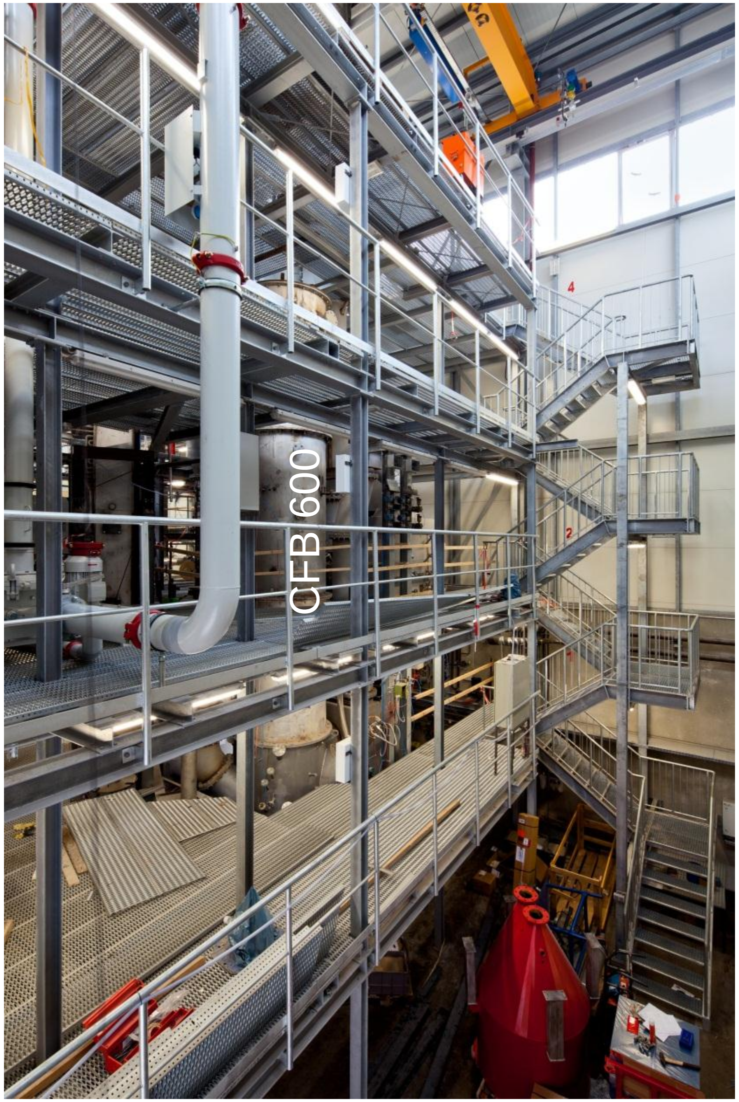


Foto: Thomas Ott

Hot Commissioning CFB600
Carbonator / Air Reactor

August 2010

CFB 600 Riser

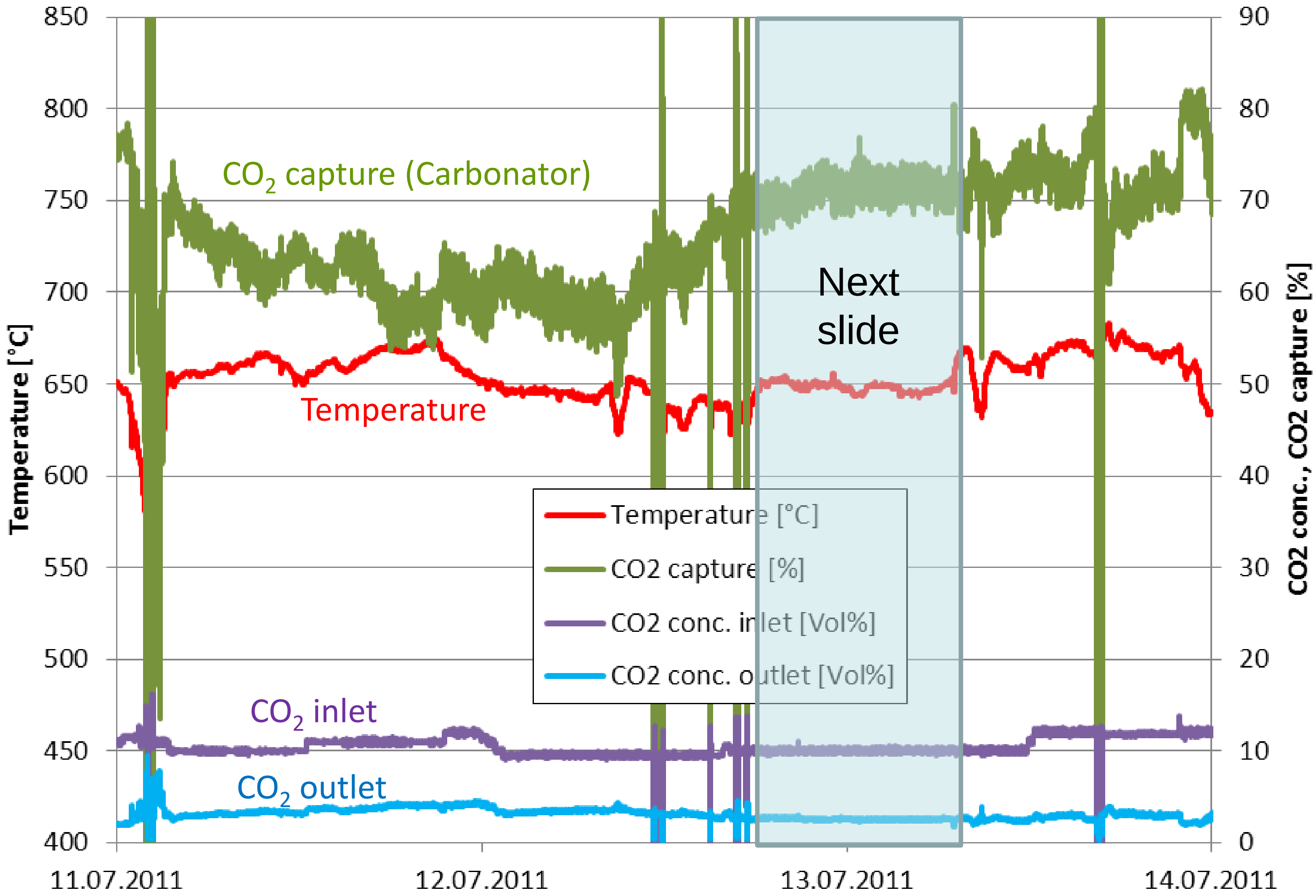
Start up Burner

Nozzle Grid Deassembly

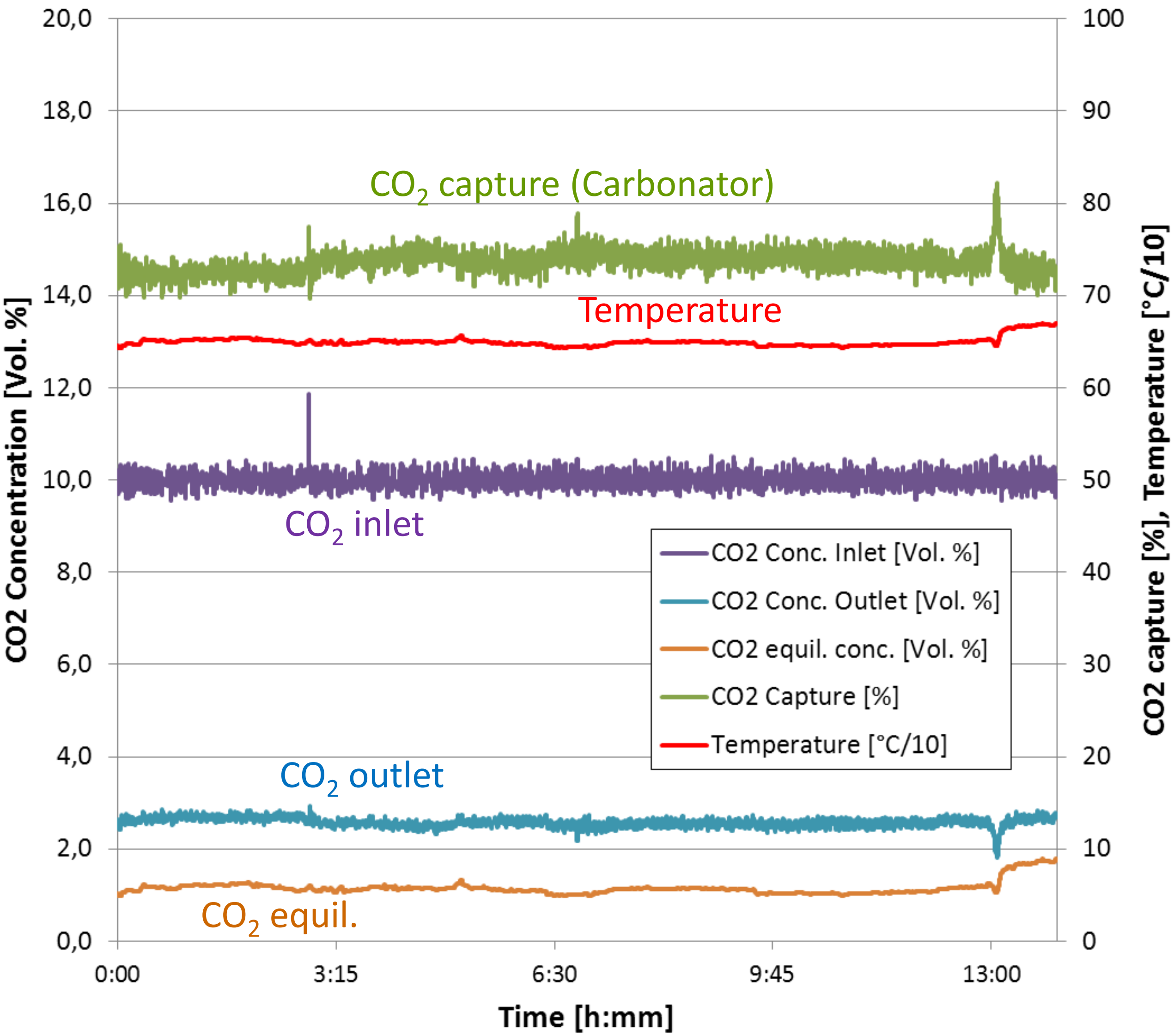
Hot Commissioning CFB 600
Operation of Start up Burner

LISA- Test campaign 5 weeks: View on 3 days continuous operation

CFB 600 Carbonator



LISA Carbonate looping – View on 13 hours stationary operation



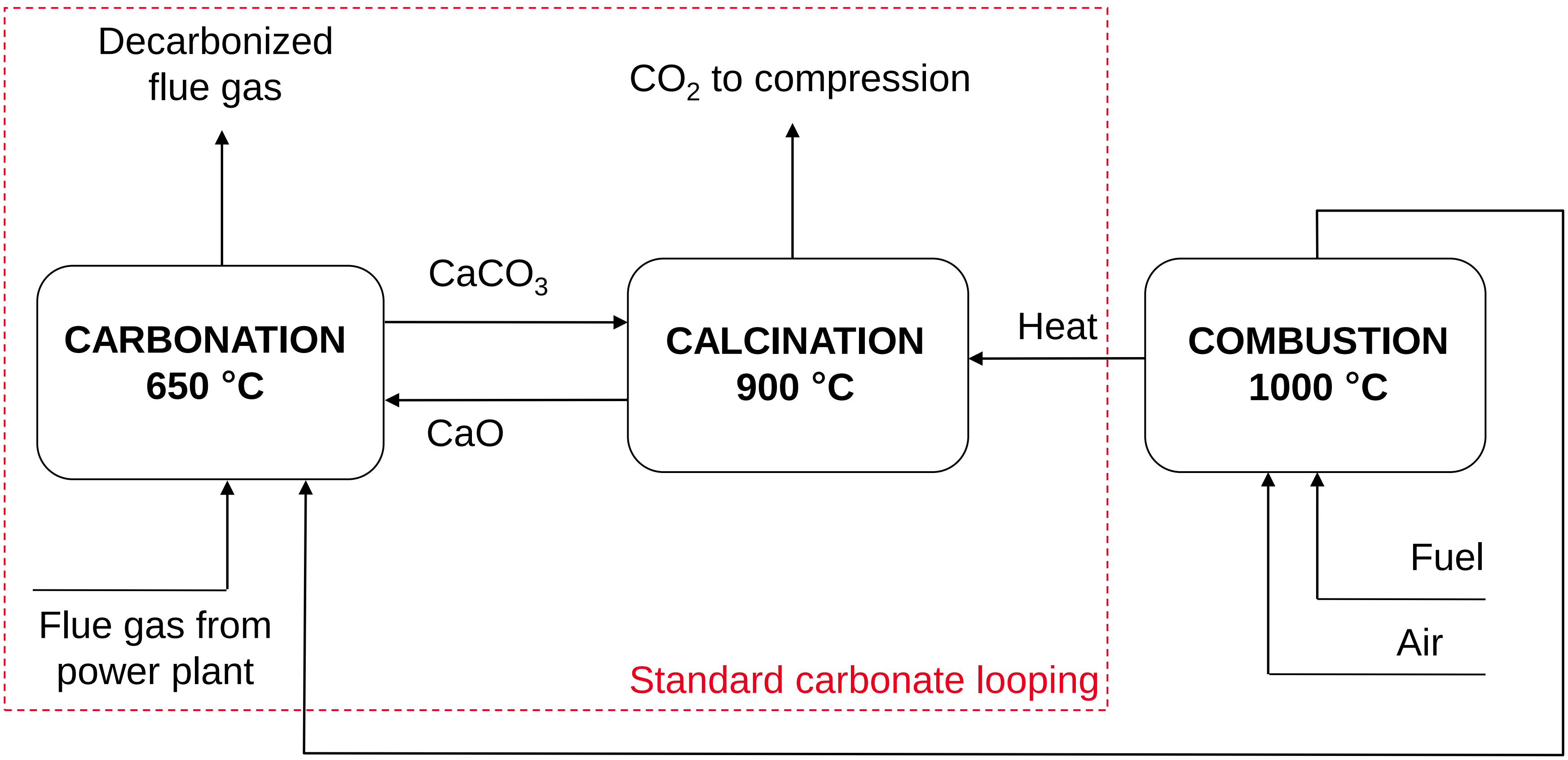
Air flow: ~1200 std. m³/h
CO_2 flow in: 134 std. m³/h

CO_2 capture limited by maximum gas firing rate in the calciner (next step with coal)

CO capture nominal rates :
- Carbonator 80 %
- Calciner (Oxyfuel) 100 %
- TOTAL 90 %

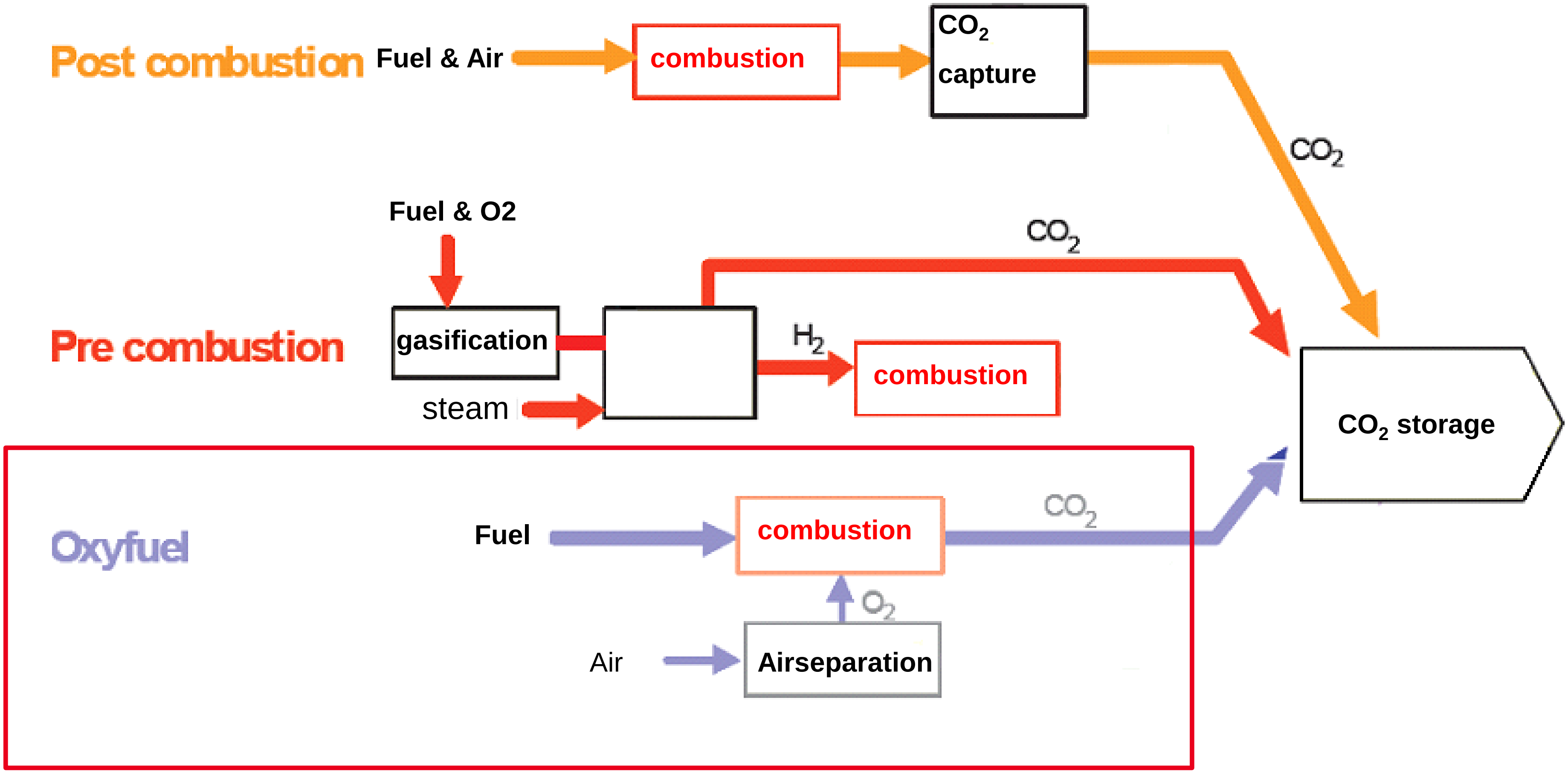
Autothermal operation in carbonator (no pre-heating, no burner)

CARINA: Indirectly heated carbonate looping process



- Heat for calciner supplied by external combustor
- No oxygen required for calcination
- Increased plant efficency

Possibilities of Carbon Capture and Storage (CCS)



Pre-Combustion Technology

Integrated Gasification Combined Cycle (IGCC-CCS)
complex process, high costs, high energy demand

Oxyfuel Technology

Cryogenic O_2 Production (high energy demand) efficiency loss ($\Delta\eta$~10%- units)

-> Alternative: **Chemical Looping** (Total $\Delta\eta$ < 4% - units)

Eff. Loss CO_2 capture : $\Delta\eta$ < 1 % - units (w/o compr.)
CO_2-compression: $\Delta\eta$ ~ 3 %- units
Total $\Delta\eta$ ~ 4 % - units
CO_2 mitigation costs ~10 EUR/ t CO_2

Oxyfuel Staubfeuerung: Pilotanlage

- Schwarze Pumpe (Vattenfall)

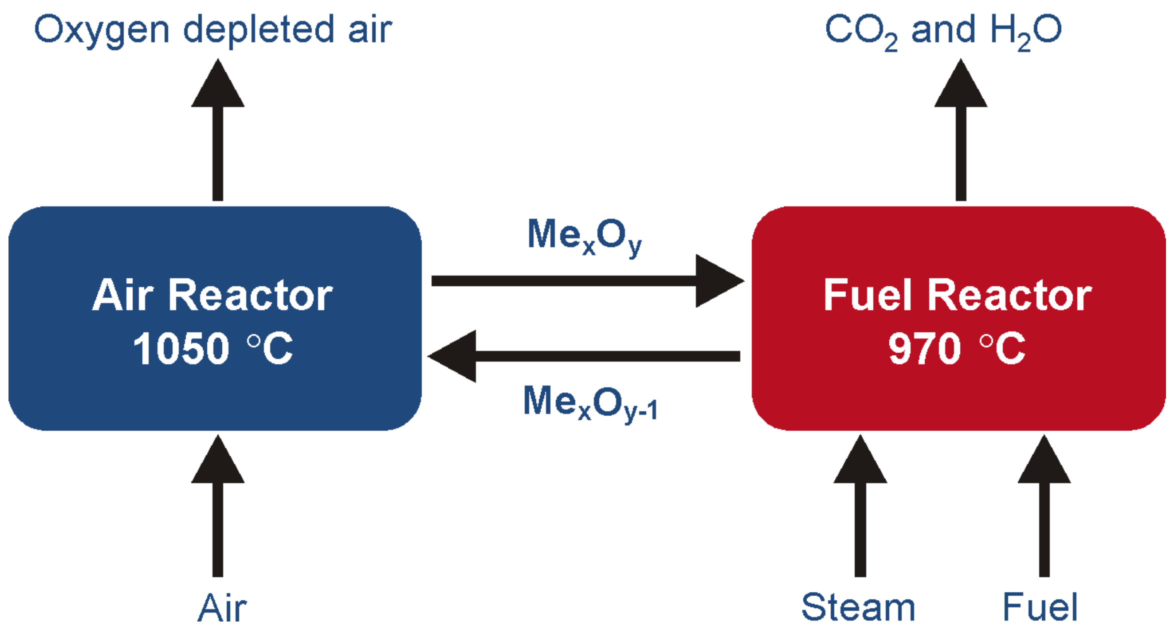
- IBN September 2008
- Leistung 30 MW_{th}
- Investitionen: 70 Mio €
- CO_2-Produktion: 9 t/h
- O_2-Bedarf: 10 t/h
- Dampftemperatur 330°C

Quelle: Vattenfall, Energy20.net (mod)

- Δη ≈ 12,5 %-Punkte

Category: Oxyfuel Chemical Looping

ECLAIR - Emission Free Chemical Looping Coal Combustion Process



Oxidation

$$2\ Me_xO_{y-1} + O_2 \rightarrow 2\ Me_xO_y$$

Reduction (global balance)

$$2\ Me_xO_y + C \rightarrow 2\ Me_xO_{y-1} + CO_2$$

CLC Test Rig – Concept simplified

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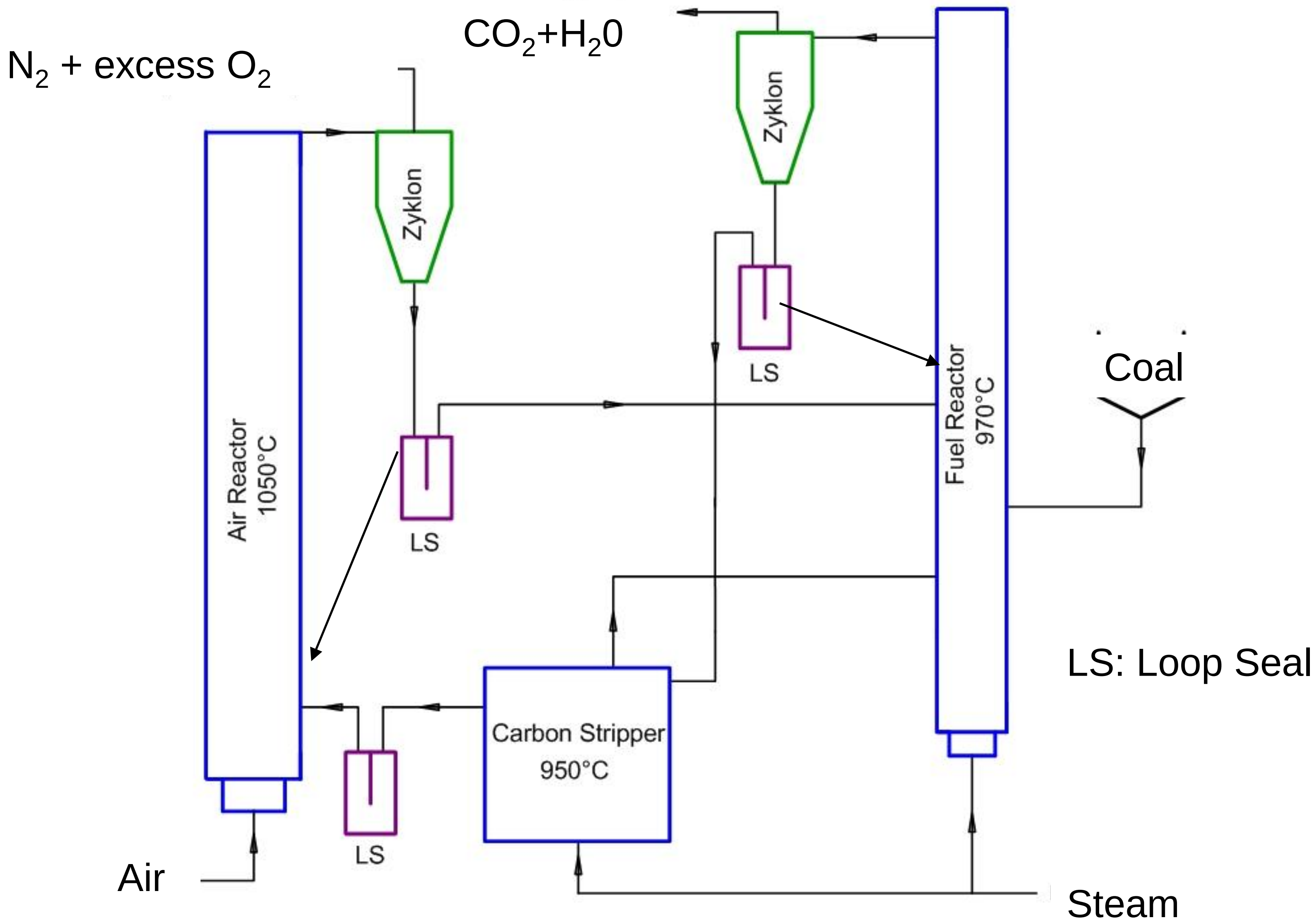
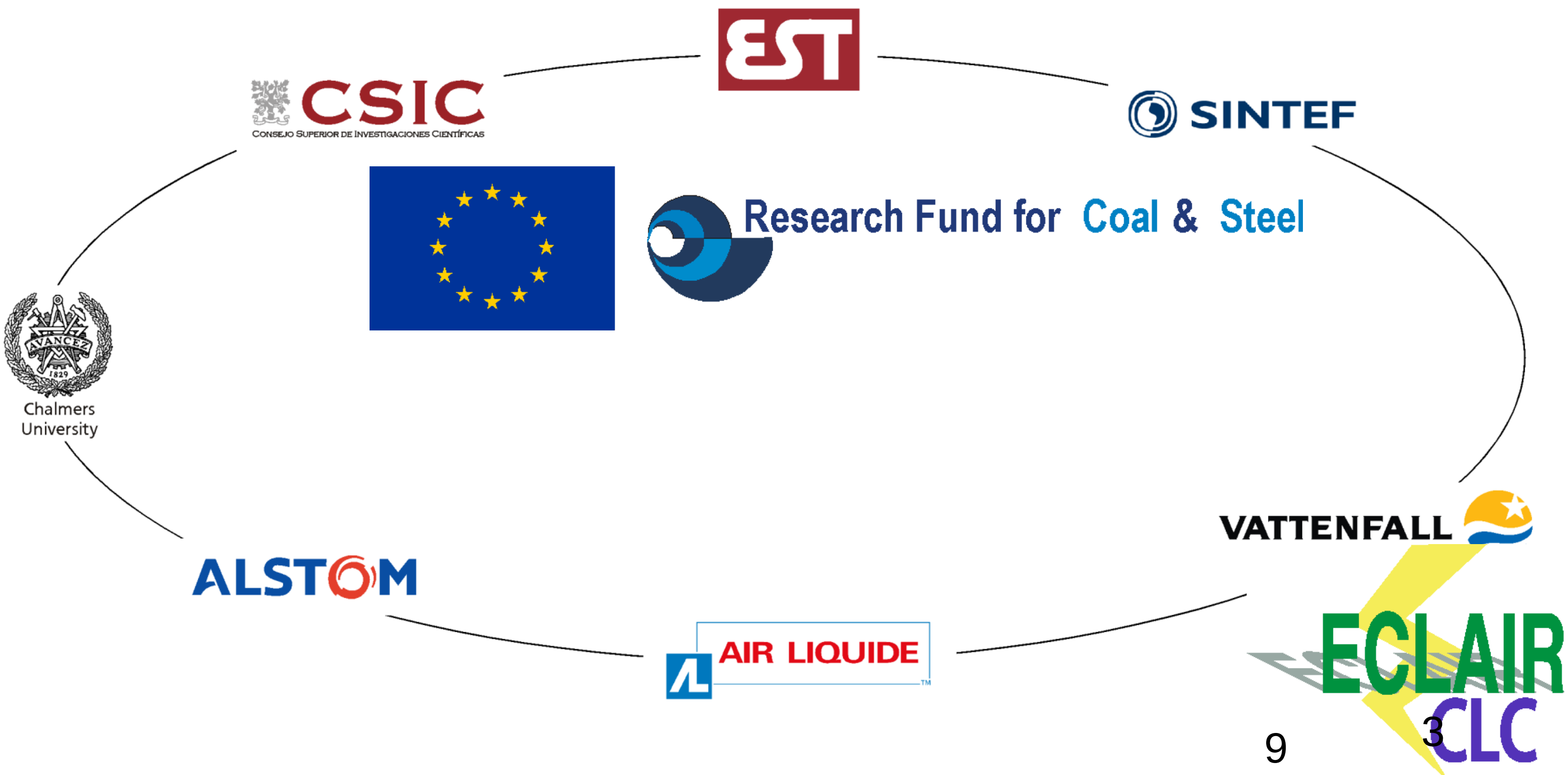


ECLAIR - **E**mission Free **C**hemical **L**ooping Co**a**l Combust**i**on P**r**ocess



Pre-Combustion Technology

not feasible

Oxyfuel Technology

High energy demand for O_2 Production (cryogenic ASU)

-> Alternative: **Chemical Looping** (fluidized bed based)

Post Combustion Technologies

e.g. **MEA scrubbing**

+ several references

- high cost
- spent sorbents -> environmental
- high steam/energy demand

-> Alternative: **Carbonate Looping**

Benefits of our investigated processes

- lower energy demand (less than 50 % compared to other CCS processes)
- low CO2 mitigation costs
- natural operating supplies (limestones, ores)

LISA : retrofit for existing plants possible, high efficiency,
20 € /t CO2 avoided

CARINA: retrofit for existing plants possible, **highest** efficiency

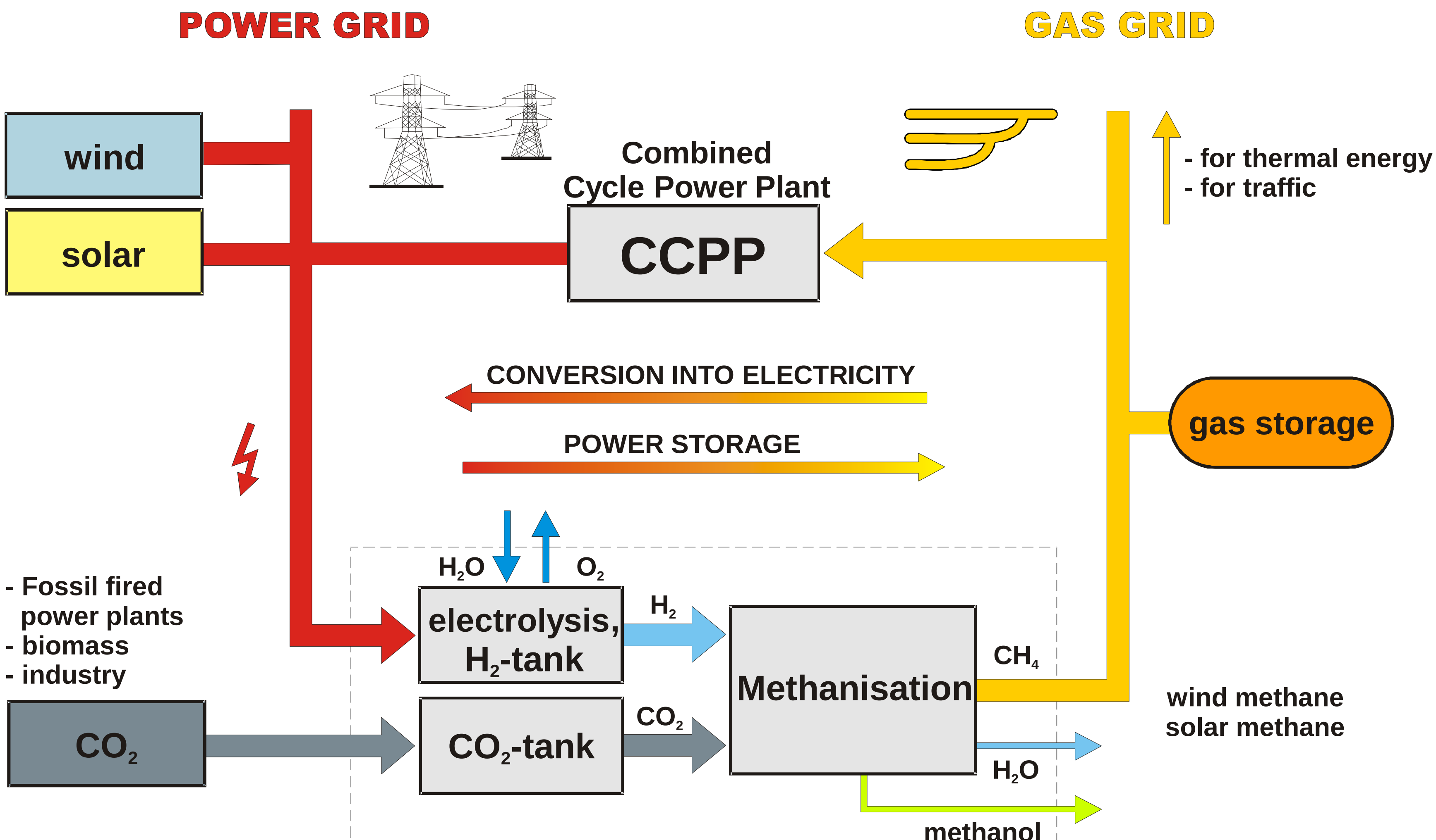
ECLAIR: new installations, **highest** efficiency
10 € /t CO2 avoided

Einsatz von CO_2 für :

- Enhanced Oil Recovery (EOR), EGR (Anwendungen u.a. in USA)

  → Erhöhung der Ausbeute von Lagerstätten um 50-70 %

- Speicherung in unterirdischen Hohlräumen (Sleipner-Field/Norwegen etc.)
- CO_2 für technische Anwendungen und Nahrungsmittelindustrie
- CO_2 zur Kunststoffproduktion (z.B. Polycarbonate, Polyurethane)
- CO_2 zur Algenproduktion, Verbesserung des Pflanzenwachstums
- CO_2 zur „chemischen Speicherung“ von Strom



Source: Sterner

Danke für Ihre Aufmerksamkeit

2nd International Conference on Chemical Looping Combustion

26.-28. September 2012
at TU Darmstadt