Cutting the cost for biogenic CO_2

– the principles and development status of Chemical-Looping Combustion (CLC) of biomass

NIM Industry Insights Series – Carbon Shift: Redefining Industry Through CCUS

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ACLOUD
Advancing chemical-looping combustion of domestic fuels

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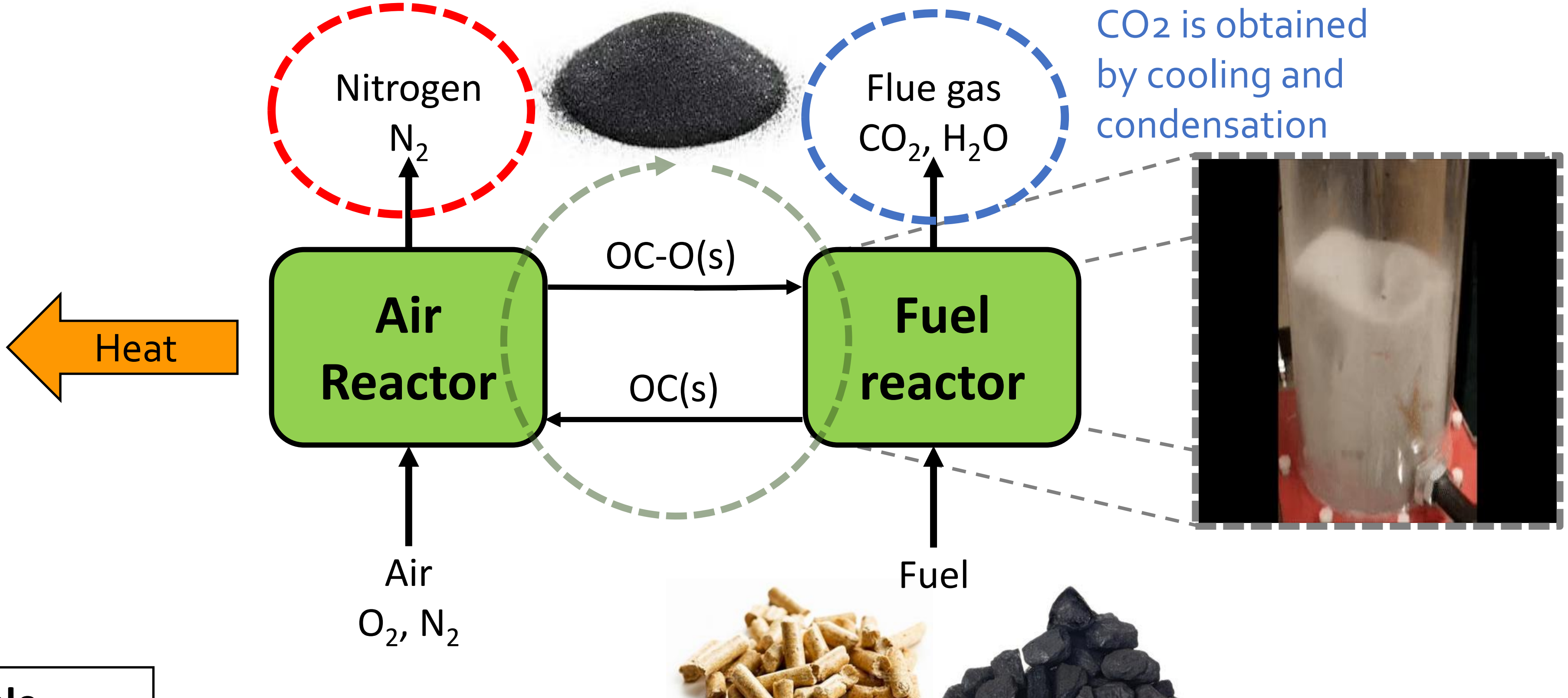
Content

- The case for Chemical-Looping Combustion.
- ACLOUD project pitch and activities.
- CLC current status and outlook.

Chemical-Looping Combustion (CLC)



Example
Fuel = CH_4
OC-O = Fe_2O_3
OC = Fe_3O_4

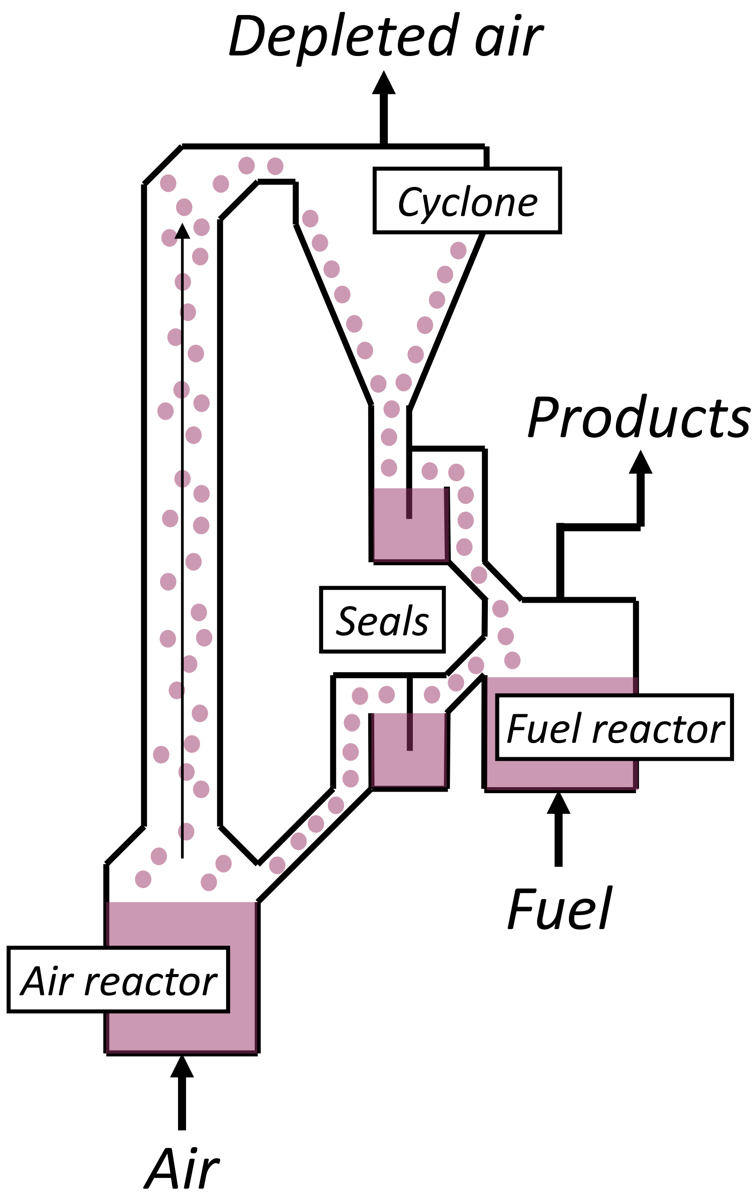
Fuel reactor: $CH_4 + 12Fe_2O_3(s) \rightarrow CO_2 + 2\ H_2O + 8Fe_3O_4(s)$

Air reactor: $2\ O_2 + 8\ Fe_3O_4(s) \rightarrow 12Fe_2O_3(s)$

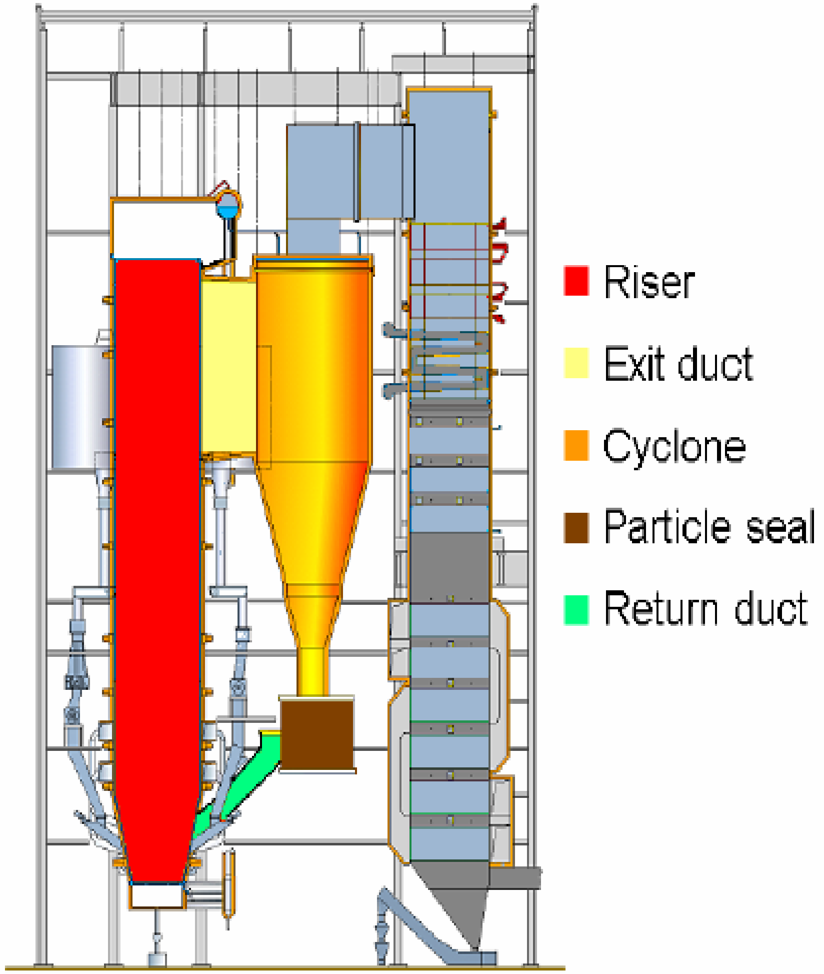
Total reaction: $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

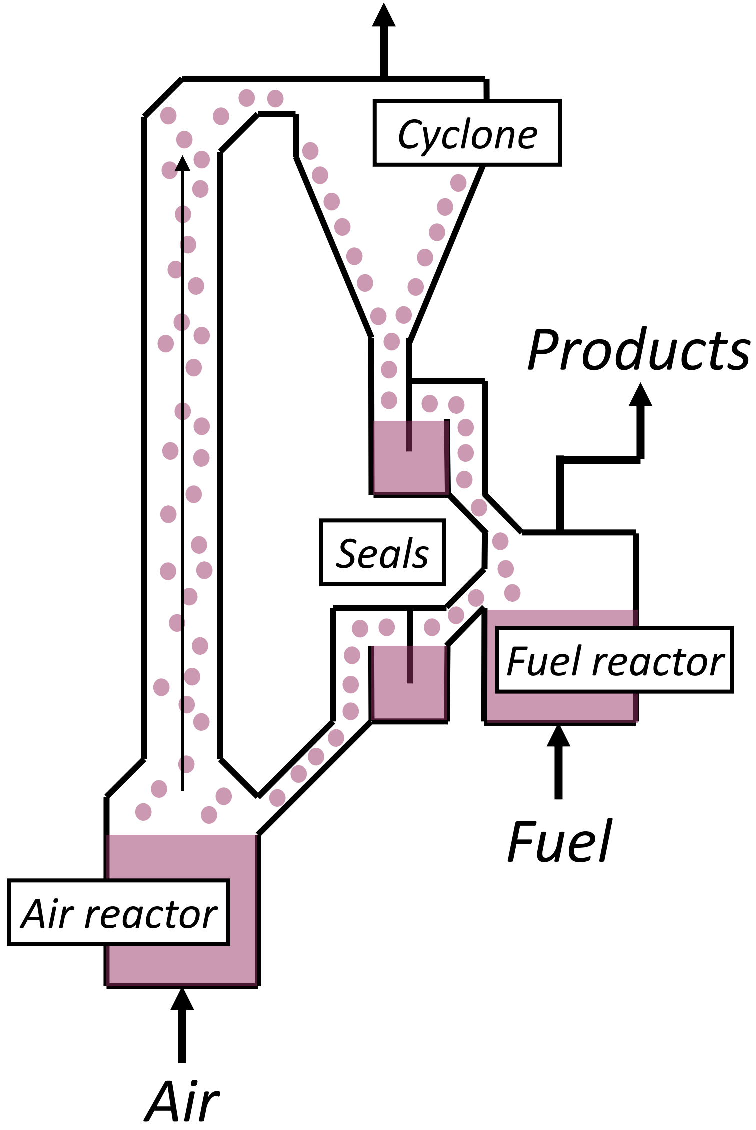
Basic reactor design

- Sand-like particles of oxygen-carrier material (0.1-0.4 mm) as bed material.
- High gas velocity (2-5 m/s) in the air reactor which acts as riser, particles are blown upwards and into a cyclone.
- The particles are transported by gravity to the fuel reactor in which they are reduced by fuel, then continues to the air reactor.
- Gas leakage between the reactors is prevented by fluidized particle seals.
- Typically, near atmospheric pressure and temperature 800-1000°C.
- Many variations has been proposed and tested. Still, the basic setup serves its purpose well.



Circulating Fluidized Bed boiler (CFB)





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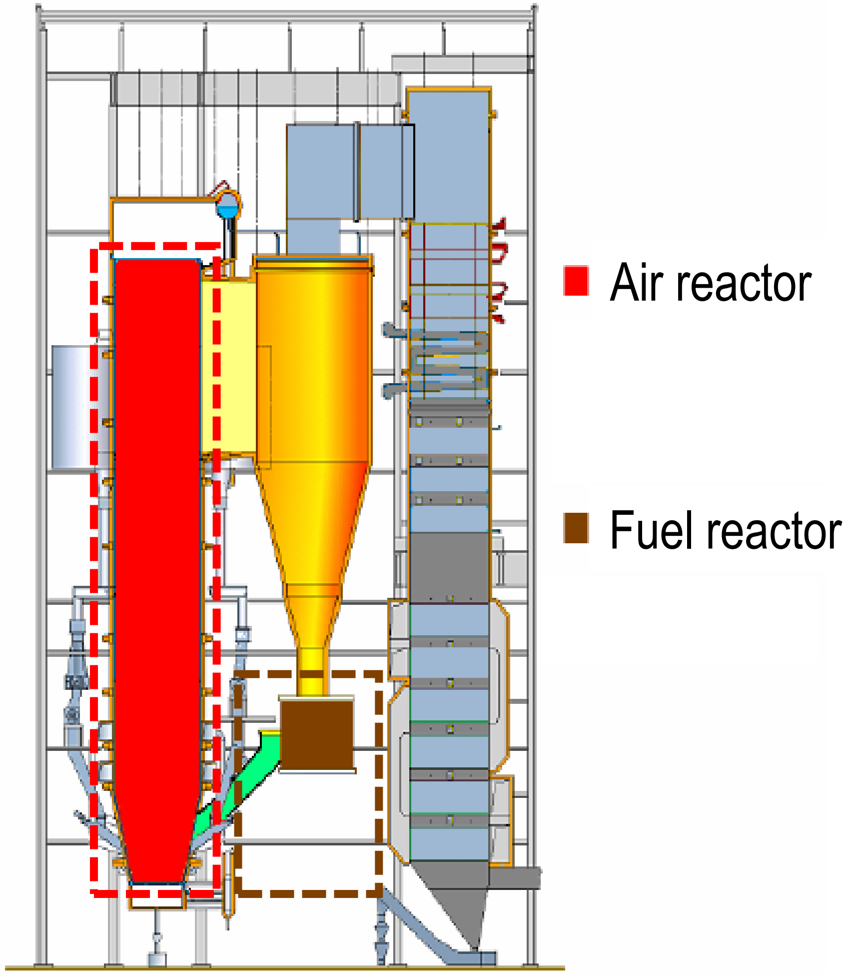
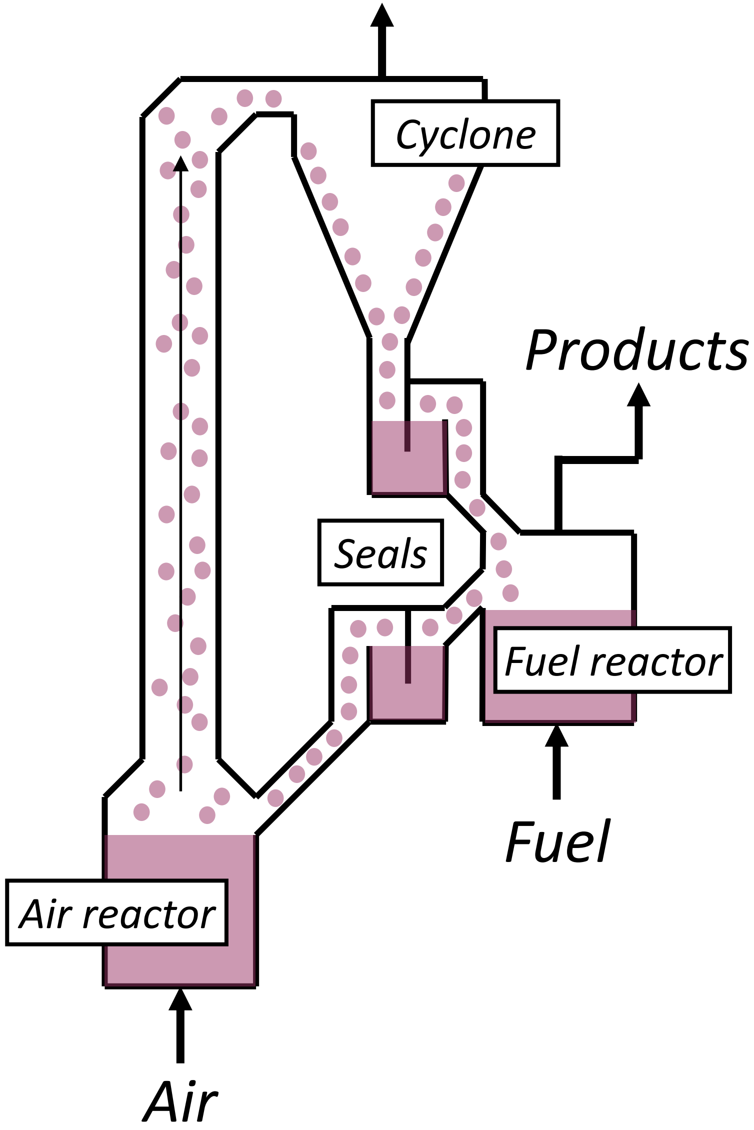




Why even bother with CLC?

- CLC can reduce the energy penalty for CO_2 capture. In theory, there is no energy penalty compared to conventional combustion.
- CLC can have close to 100% capture rate without extra costs or efforts.
- Compared to post combustion, CLC has low CAPEX and small footprint. Everything can fit within the confined walls of a CFB boiler.
- CLC does not require harmful chemicals. The oxygen carrier can be mineral ores (e.g. ilmenite ore, iron ore) or byproducts (e.g. sulfide-ore smelter slag) from mineral industries.
- CLC has potential to reduce CO_2 capture cost for several applications. For solid fuel combustion, most studies suggests ≈20-25 euro/ton$_{CO_2}$.

ACLOUD Project Pitch

- In northern Europe, biomass and forestry waste are important domestic fuels.
- In Europe as a whole, the use of waste-derived fuels seems destined to increase.
- Difficult to convert, being inhomogeneous and rich in problematic ash species.
- CLC could be an ideal conversion technology for difficult fuels. It provides inherent CO_2 capture, O_2 buffering to counter inhomogeneity and also separates heat-transfer surfaces from ash.

PROJECT CONSORTIUM

Universities
Chalmers University of Technology (CTH)
Technical University of Darmstadt (TUDA)
Åbo Akademi University (AAU)

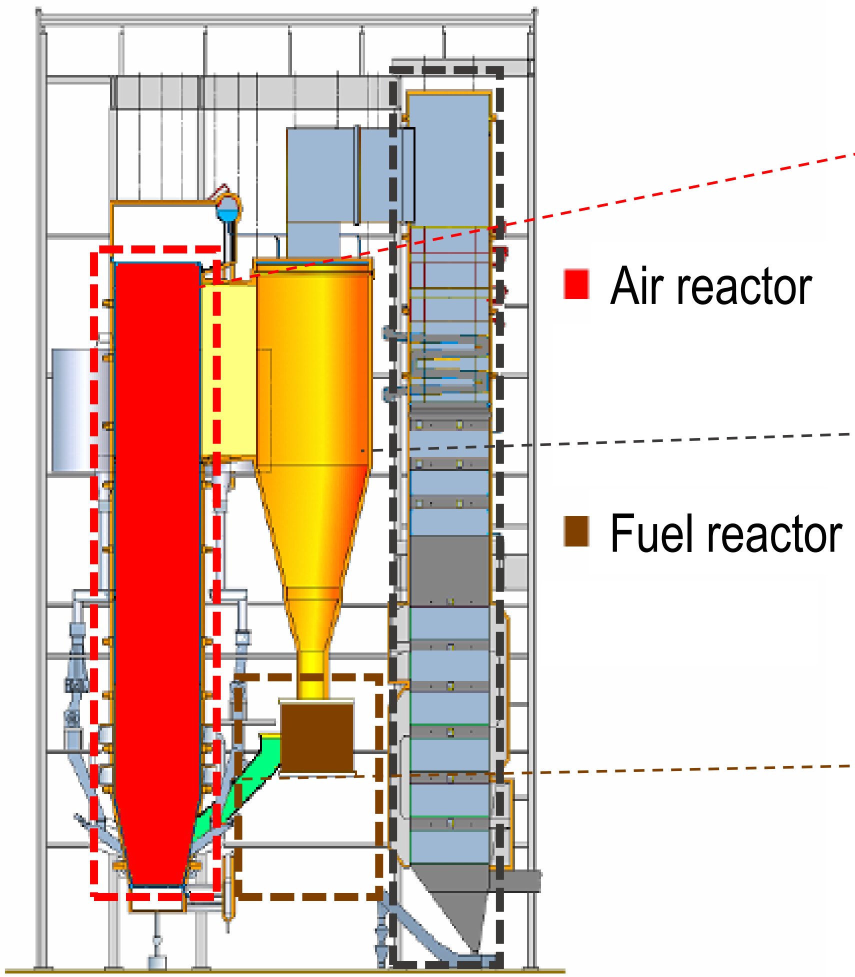
Technology providers
Sumitomo SHI FW Energia Oy (SFW)
Alleima AB (ALLE)

Consultancy company
CheMin GmbH (CHEM)

End users
Stockholm Exergi (STEX)
Skövde Energi (SKEN)

Research institute
Research Institute of Sweden (RISE)

ACLOUD Project Pitch

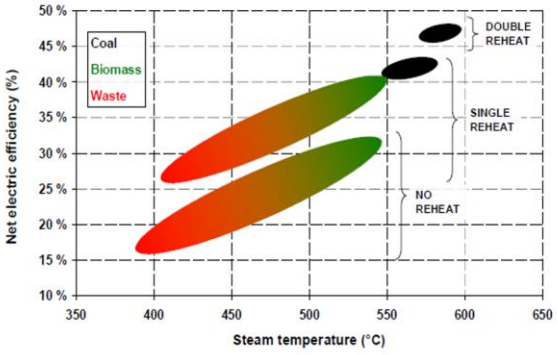


- No or minimal ash species
- Atmosphere mainly N_2 and O_2
- Temperature 900-1050°C
- Air factor can be reduced
- ≈100% of heat generation
- ≈70% of total gas flow

- Minimal ash and deposits
- Slightly reduced heat flow
- Reduced gas radiation

- Atmosphere mainly CO_2 and H_2O
- Concentrated ash and impurities
- Temperature 900-1050°C
- ≈Adiabatic reactor
- ≈30% of total gas flow
- CFB, dual-CFB or other design?
- Separate convection path?
- Flue gas conditioning?

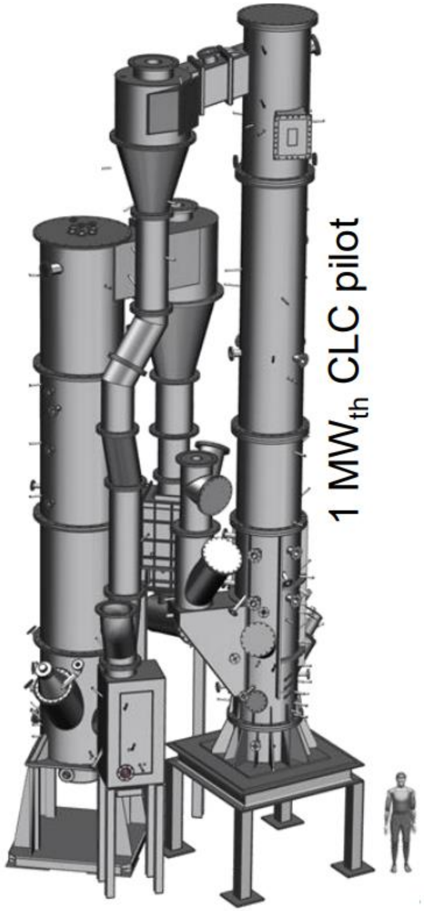
No aggressive ash species here means that steam data can be increased, which means electric efficiency could be improved.



Project Activities

- Demonstration at 1 MW scale with at least two relevant domestic fuels.
- Work on pilot and lab scale related to fuel conversion pathways and ash chemistry. This includes development of new analysis and measurement techniques.
- Corrosion and material studies, including applied on 1 MW and 10 kW pilot reactors.
- Economic performance and environmental impact for key applications, such as e.g. waste-to-energy and combined heat-power.

10 kW lab pilot



Current status of CLC

- Demonstrated in >>50 different pilot reactors for in total >>12000 h, using all sorts of fuels and a huge range of oxygen carriers. ≈80% of global experience is in Europe.
- Demonstrated up to 5 MW_{th} scale (China 2024), but most work is at the scale 0.1-100 kW_{th}.
- The preparation, use and logistics of oxygen carriers have been demonstrated in >12 full-scale boilers in Sweden, but without CO_2 capture.
- 100% fuel conversion and 100% CO_2 capture feasible with gaseous fuels.
- With coal and biomass >>90% fuel conversion and >>90% CO_2 capture is a realistic target. It is clear that dedicated flue gas conditioning and cleaning needs to be designed, but this is mainly an engineering challenge.

Takeaways for CCUS

- Chemical-Looping Combustion represents a mid-term possibility for significantly reducing cost for biogenic CO_2 for storage and utilization.
- Needs to be integrated with solid fuel applications such as e.g. Combined heat and power, waste incineration, or bark boiler on pulp mills.
- Current key challenge is to take the concept to the next level, which would be design and deployment of industrially relevant units. This will require much more active involvement of capable engineering companies.
- I believe this step is hampered mainly by the tendency of potential CO_2 customers to consider only off-the-shelf technologies, and the uncertain regulatory framework for biomass and negative emissions in Europe.
- Help and ideas about how to realize this final step are much appreciated!

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