Bio-Flex CLC

Flexible chemical looping combustion for combined heat and power production from biogenic residues with negative emission (Bio-FlexCLC)

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Chemical Looping Combustion (CLC)

Two interconnected Fluidized Bed reactor with oxygen carrier as bed material.

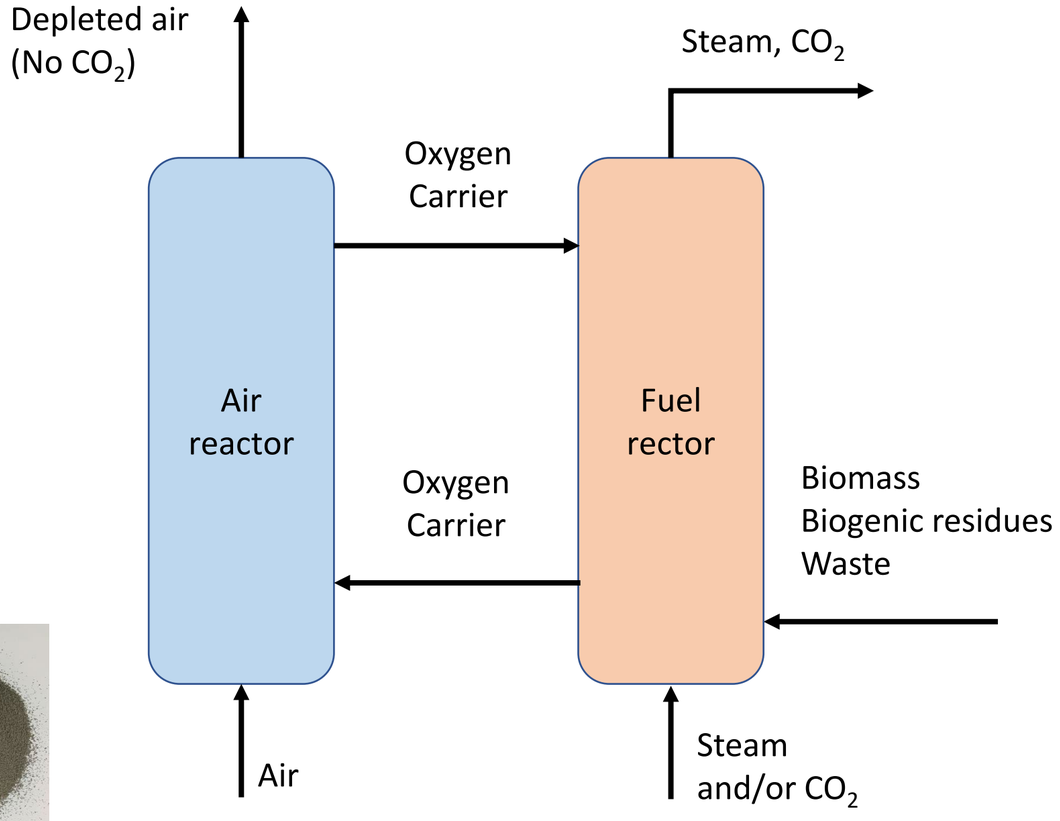
Oxygen carrier (OC):

$$Me_xO_{y-1} + \frac{1}{2}O_2 \leftrightarrow Me_xO_y \qquad (\Delta H < 0)$$

Me_xO_y: Metal oxides particles in the range of 100–500 µm, such as Fe, Mn, Cu or Ni oxides

OC can be:

- natural ores such as ilmenite
- industrial waste materials such steel slag convertor and cupper slag
- Synthetic material such as pervoskites



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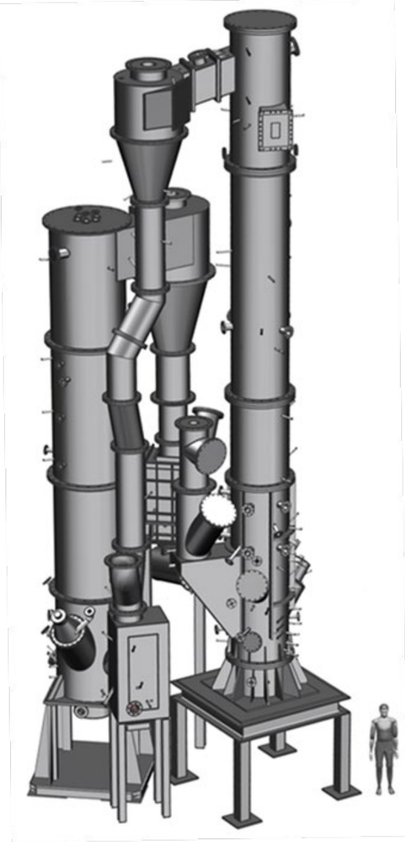
Advantageous of CLC

- CLC could facilitate CO_2 capture at exceptionally low cost (roughly 20 €/ton_{CO2})
- There is no energy penalty for gas separation and close to 100% CO_2 capture can readily be realized
- Within the CLC system, ash and emissions will be concentrated to the fuel reactor, where the gas flow is reduced to a quarter compared to conventional combustion
- The CLC reactor system would share a layout and size similarity with CFB boilers, known for their scalability to larger dimensions
- Since CLC offers inherent CO_2 capture, the CO_2 capture process automatically adapts to load variations, eliminating the cost penalties associated with significant capital investment costs for post-combustion capture or oxy-fuel infrastructure
- Previous studies have indicated that CLC results in minimal or negligible emissions of NOx and reactive impurities
- CLC offer potential benefits in terms of corrosion resistance and reduced emissions of harmful elements
- CLC could generate higher temperature steam suitable for supercritical steam cycle leading to higher electrical efficiency



1 MW unit at TU Darmstadt

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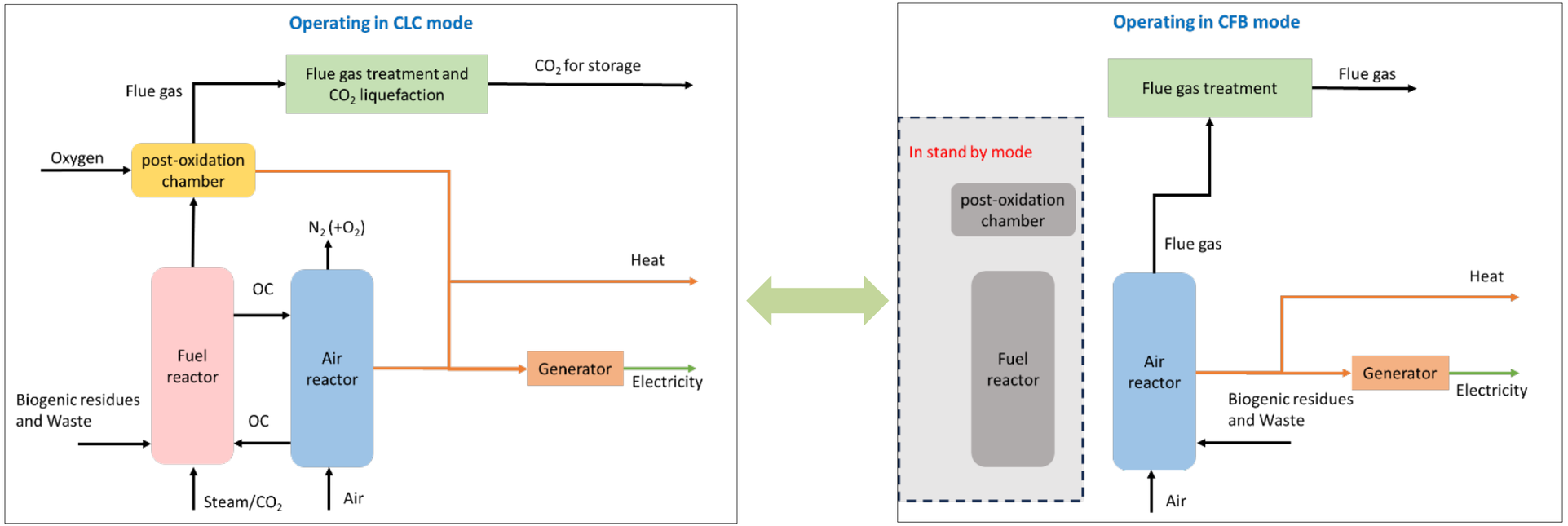
Bio-FlexCLC project

- The concept is based on dual circulating fluidized bed reactors which can operate in CLC mode while both reactors are in use or switch to conventional CFB operation when only one reactor is in use.
  - operating in CLC mode enables CHP production with negative emissions at low-cost while the concept is flexible to switch to CFB boiler mode to produce CHP with net-zero emissions



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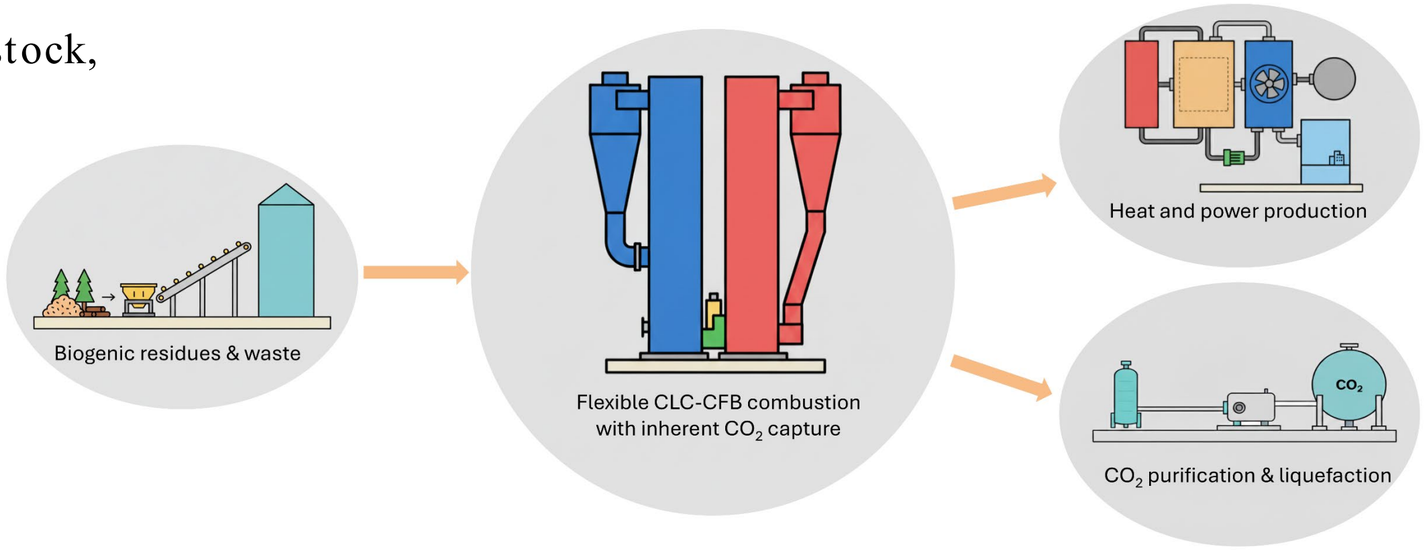
Bio-FlexCLC Advantageous

1. Strong compatibility with existing infrastructure, as the technology is based on fluidized bed combustion, a common technology for heat and power production,
2. Have the flexibility to switch to conventional Circulating Fluidized Bed (CFB) combustion if market conditions are not amiable for carbon capture,
3. Have higher efficiency and lower cost and energy penalty and for CO_2 capture,
    - Negative emission (CDR) at low cost
4. Could utilize biogenic residues and wastes as feedstock,
5. Have flexibility towards load fluctuations,
6. Have low corrosion with improved steam data for improved electrical efficiency,
7. Reduce SOx and NOx emissions



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Methodology and Execution

To further understand CLC of biogenic residues

CLC operation mode with four different biogenic residues, e.g. agricultural and forestry residues, and investigate fate of ash species

Black pellets

Olive stones

Branches & treetops

RDF

To reduce the emissions of harmful gases and particles

Developing the gas cleaning procedure to reduce SOx, NOx, aromatics, and particle emissions including CO2-Liquifaction unit

portable gas cleaning pilot plant

To improve the conversion of fuel by adding packings in the fuel reactor and post oxidation chamber

Reduce the fraction of unconverted fuel in the fuel reactor (below 10% oxygen demand, or above 90% gas conversion);

Reach >99% conversion in the fuel reactor and post post-oxidation step

10 kW CLC pilot reactor (left) and 20 kW CLC pilot plant (right)

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Methodology and Execution

To evaluate the flexibility of Bio-FlexCLC operation

Changing the thermal input in the Bio-FlexCLC operation from 100% to 75%, 60% and 50%

Develop strategies for optimized operation at heat-to-power ratio of 1:1, 2:1, and 3:1

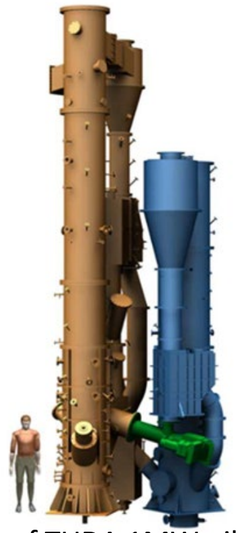
To evaluate the economic and environmental performance of the process concept

Evaluate the environmental and economic performance for at least two locations for adopting Bio-FlexCLC in the regions in transition from fossil fuels

To demonstrate Bio-FlexCLC at MW-scale with downstream treatment and liquefaction

Operate the 1 MW bio-FlexCLC plant in CLC-CFB modes with downstream gas treatment and liquefaction for at least 200 hours and reach >95% CO_2 capture

To design a full chain 100 MW commercial scale Bio-FlexCLC plant for CHP production from biogenic residues



Drawing of TUDA 1MW pilot plant

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Bio-FlexCLC

Start date: June 2024

Duration: 48 months

Received Approximately 3.9 Million Euros from European Commission through Horizon Europe Program

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