Chemical-Looping Combustion

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CLC consortium and Bio-CCS in Sweden

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Workshop on Sustainability and
GHG impact of Bio-CC(U)S
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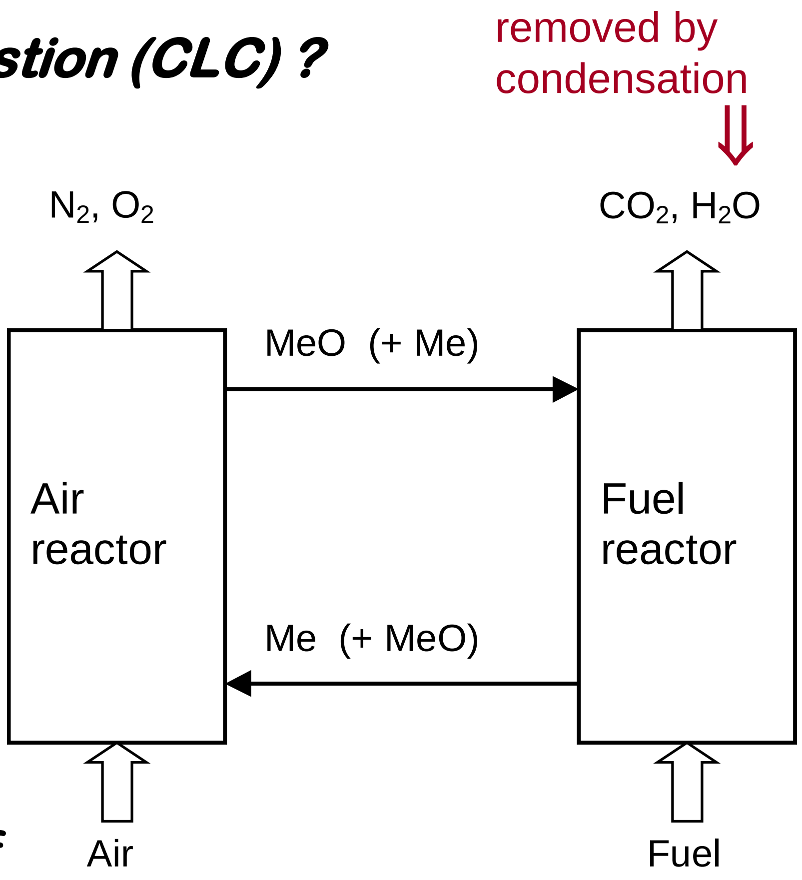
Why chemical-looping combustion (CLC) ?

Oxygen is transferred from air to fuel by metal oxide particles

Inherent CO_2 capture:

- fuel and combustion air *never mixed*
- ***no active gas separation needed***
- large costs/energy penalties of gas separation avoided

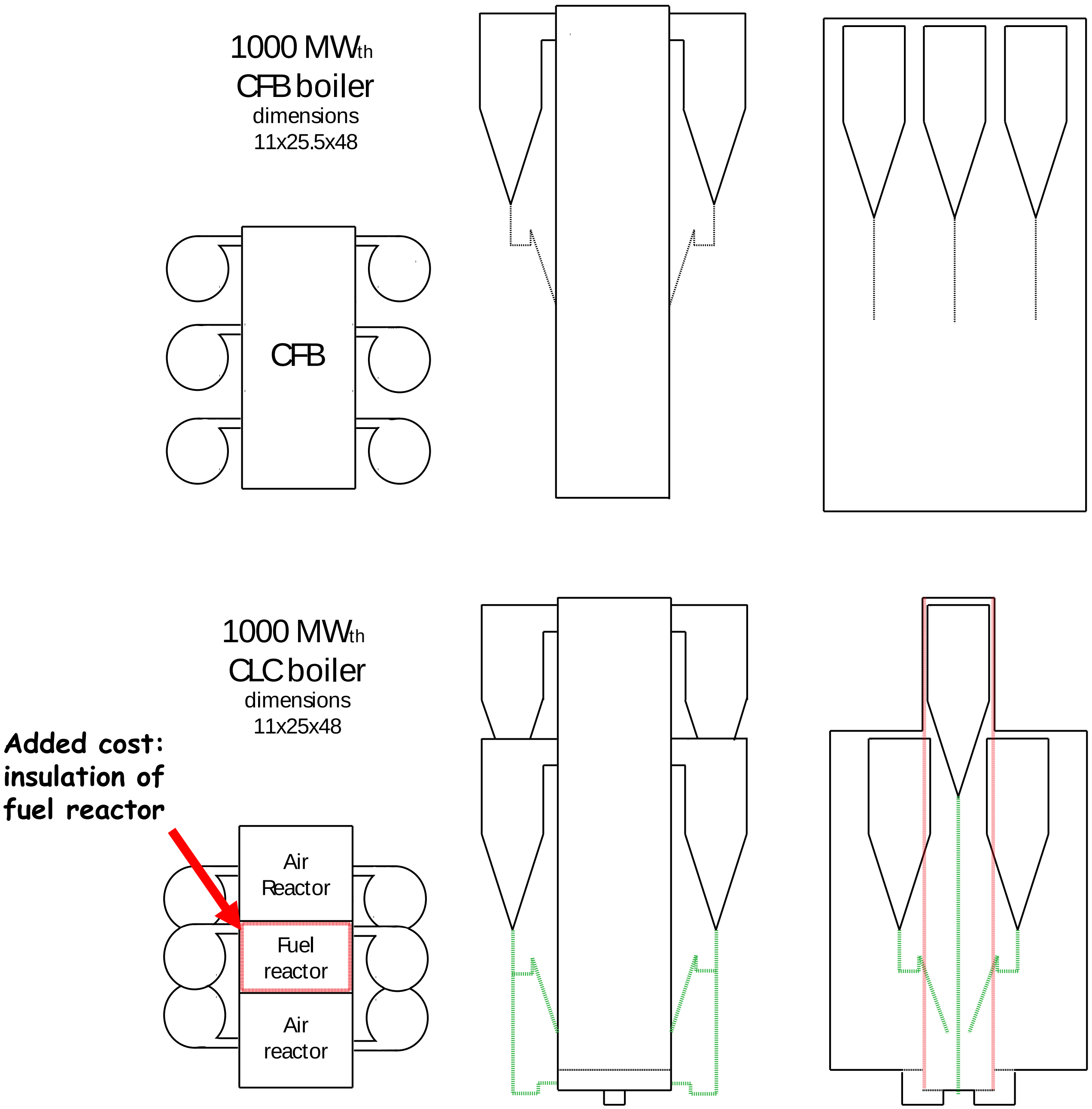


- **Potential for real breakthrough in costs of CO_2 capture**

But does it work ?

- **CLC operation worldwide**
  - 34 pilots : 0.3 kW – 3 MW
  - >9000 h operation: of which solid fuels >3000 h

- **CLC with *solid* fuels**
  - Low cost oxygen carriers can be used
  - Incomplete conversion/capture
    - Some oxy-polishing needed, estimate: 10-20%
    - Up to 98% CO_2 capture attained
  - Sufficient experience in smaller pilots
    - Ready for scale-up !!



Fuel reactor, cyclones, ducts and post-oxidation chamber: 2500 m²

Cost: 1500 €/m²

Added cost of fuel reactor:

4 M€

⇒ 0.4 M€/year

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2 Mton CO_2/year

= 0.2 €/ton CO_2

From: Lyngfelt, A., and Leckner, B., A 1000 MWth Boiler for Chemical-Looping Combustion of Solid Fuels - Discussion of Design and Costs, *Applied Energy* in press *(available on-line)*

Other costs

- CO_2 compression
  - Similar to other capture technologies
- Oxygen production (incomplete conversion)
  - 5-10 times less oxygen as compared to oxyfuel
- CO_2 purification
  - As in oxyfuel, option for SO_2/NO_x capture
- Oxygen carrier
  - With low cost ores, estimated to 1-4 €/tonne CO_2
- Minor costs, >1 €/tonne
  - Fuel grinding, steam for fluidization
- Total costs, estimated to 16-26 €/tonne CO_2

Estimated cost of CLC, less than half of competing technologies

Should be suitable for biomass.

- **larger biomass boilers normally use CFB technology**

Additional potential advantages

- **No pollutants in flow from air reactor**
    - **Lower air ratio possible ?**
- **Pollutants, e.g. NO_x, concentrated in CO_2 flow**
    - **Possibility to eliminate NOx emissions ?**
- **No ash/alkali from air reactor ?**
    - **Alkali leaves with flue gases from fuel reactor ?**
    - **and/or is captured by the oxygen carrier ?**
    - **No fouling/high temperature corrosion ?**
    - **Higher steam data / efficiency possible ?**
    - **Lower operational and maintenance costs ?**
    - **Problems concentrated in smaller flow from fuel reactor ?**

Strategy for full-scale demonstration of chemical-looping at low cost ?

Build dual purpose CFB/CLC, or retrofit CFB to CLC

- Low added cost of CLC plant

Skip CO_2 capture (in 1st stage)

- Major added costs can be avoided, i.e. CO_2 compression and purification, and oxygen production

Go for biomass

- Potential advantages for avoiding fouling/high-temperature corrosion, thus potential of higher steam data/higher efficiency. Pollutants (NO_x) in smaller CO_2 stream, emissions can be reduced

When the technology successfully demonstrated, add CO_2 capture (2nd stage)

CO_2 sources in Nordic countries

Finland + Sweden

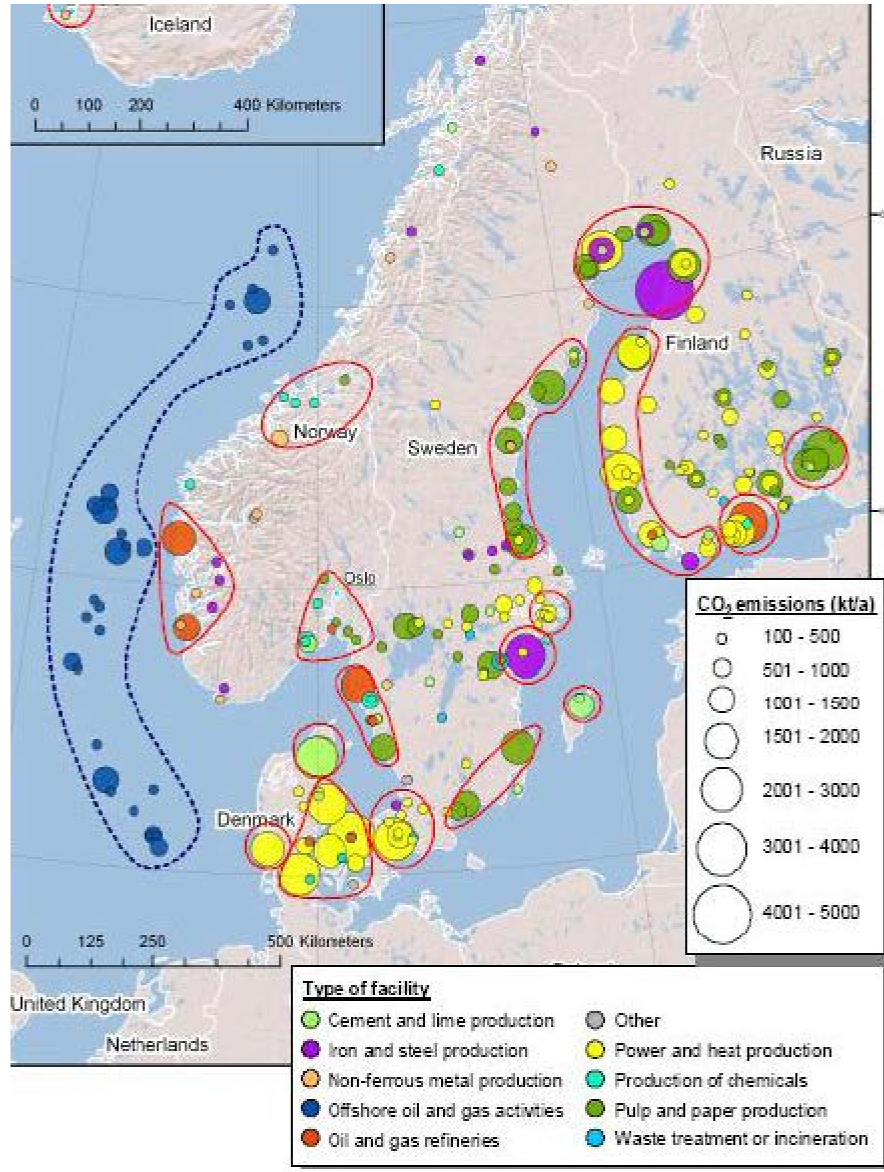
fossil CO_2 emissions:

<120 Mt/year

in addition:

>50 Mt/year biogenic CO_2
from point sources

>100 000 tons/year



Nordic countries and BioCCS

- Large biogenic emissions (Sweden + Finland)
- Very large and proven storage locations (Norway)
- Key competence in storage, Norway worldleading
- Potential synergies with industrial emission that would need storage (cement, iron & steel…)
- Key competence in CLC

Nordic Energy Research

Flagship Project

Negative CO_2

Enabling negative CO_2 emissions in the Nordic energy system through the use of Chemical-Looping Combustion of biomass (bio-CLC)

	Budget (kNOK)
Chalmers University of Technology	9258
The Bellona Foundation	2080
Sibelco Nordic AB	240
SINTEF Energy Research	6555
SINTEF Materials and Chemistry	2787
VTT Technical Research Centre of Finland Ltd	6667
Åbo Akademi University	3337
Sum:	30924

Conclusions

- **BioCCS will be needed in large scale to meet climate targets**
- **Nordic countries are very suitable for developing BioCCS**
- **Chemical-Looping Combustion has unique potential for dramatically reduced cost of CO_2 capture**
- **CLC may have significant advantages for biomass combustion**
- **Full-scale demo of chemical-looping combustion could be done at low cost (i.e. compared to other capture technologies)**

Thank you !
Questions ?

>300 publications on chemical-looping on:
http://www.entek.chalmers.se/lyngfelt/co2/co2publ.htm