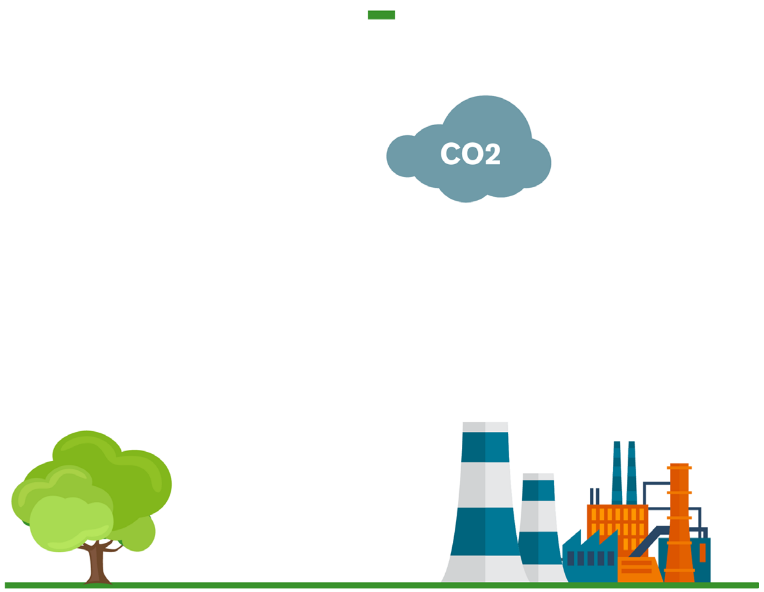
# *Introduction to the Research Environment: “Biomass Combustion Chemistry with Oxygen Carriers”*

Anders Lyngfelt




Chemical Looping with Biomass –
Role of Ash Chemistry
*May 25-26, 2021*
Chalmers University of Technology

The project is funded by
Swedish Research Council

# Chemical-Looping Combustion (CLC)

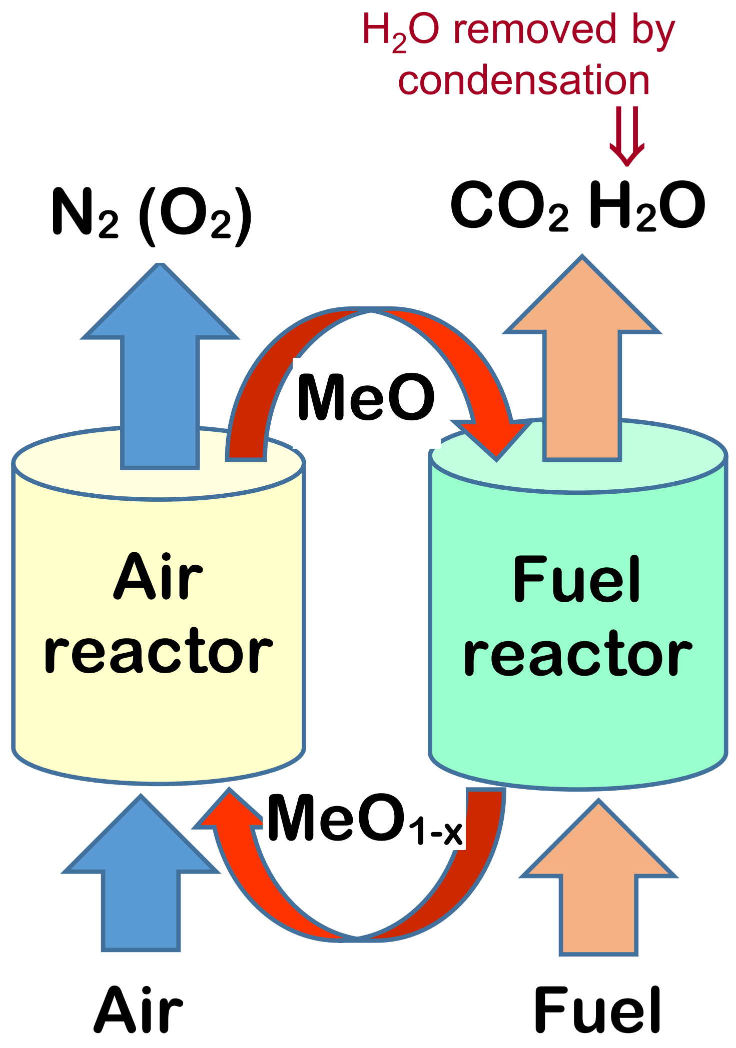
Oxygen is transferred from air to fuel by metal oxide particles

Inherent $CO_2$ capture:

- fuel and combustion air *never mixed*
- *no active gas separation needed*

***Unique potential for avoiding the large costs and energy penalty of gas separation in $CO_2$ capture.***

**$CO_2$ capture from biomass means negative emissions.**



**Biomass combustion chemistry with oxygen carriers**

*6-year project funded by Swedish Research Council*

*Cooperation between Chalmers University of Technology and Gothenburg University*

## Purpose

**Develop a novel methodology for studying fuel conversion chemistry** under relevant reducing conditions present in a CLC fuel reactor, with special focus on alkali (Na and K) and chlorine compounds because of their key roles for corrosion and catalytic processes.

**Establish the main gas-phase reaction paths of impurities compounds under (mildly) reducing conditions**. . . . . focus on alkali, and the influence of chlorine, nitrogen and sulfur precursors . . . . .

**Establish the main reaction paths between important ash impurities and iron and manganese oxides.** . . . reactions between ash impurities and the oxygen carrier particles …

**Potential effects of alkali / aggressive ash components**

Fouling / corrosion of tubes downstream in convection paths

Fouling / corrosion of boiler tubes in combustion chamber/air reactor


Agglomeration of bed material

Oxygen carrier reactivity loss

Oxygen carrier reactivity increase

Increased char gasification

**Path 1**
Alkali released in fuel reactor

No alkali in air reactor or AR convection pass.

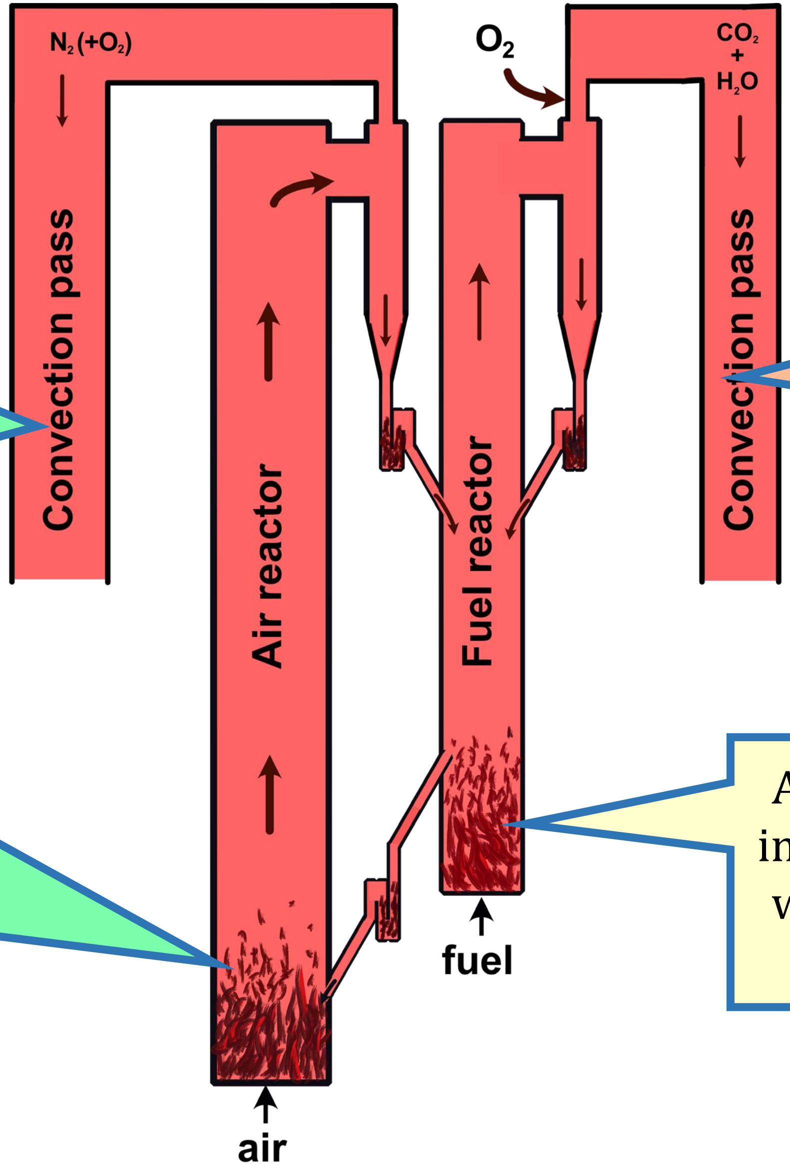
Advantage relative to normal CFB combustion?

Possibility to raise steam temperature / efficiency ?

Reduced maintenance ?

Increased availability ?

Possibility to use more difficult fuels ?




Problem concentrated to the smaller outgoing flow.

<u>Countermeasure</u>:
lowered surface temperatures on heat exchanger surfaces

Alkali released in FR and leaves with out-going gas flow

**Path 2a**

Alkali binds permanently to oxygen carrier, without causing problems

No alkali in air reactor or AR convection pass.

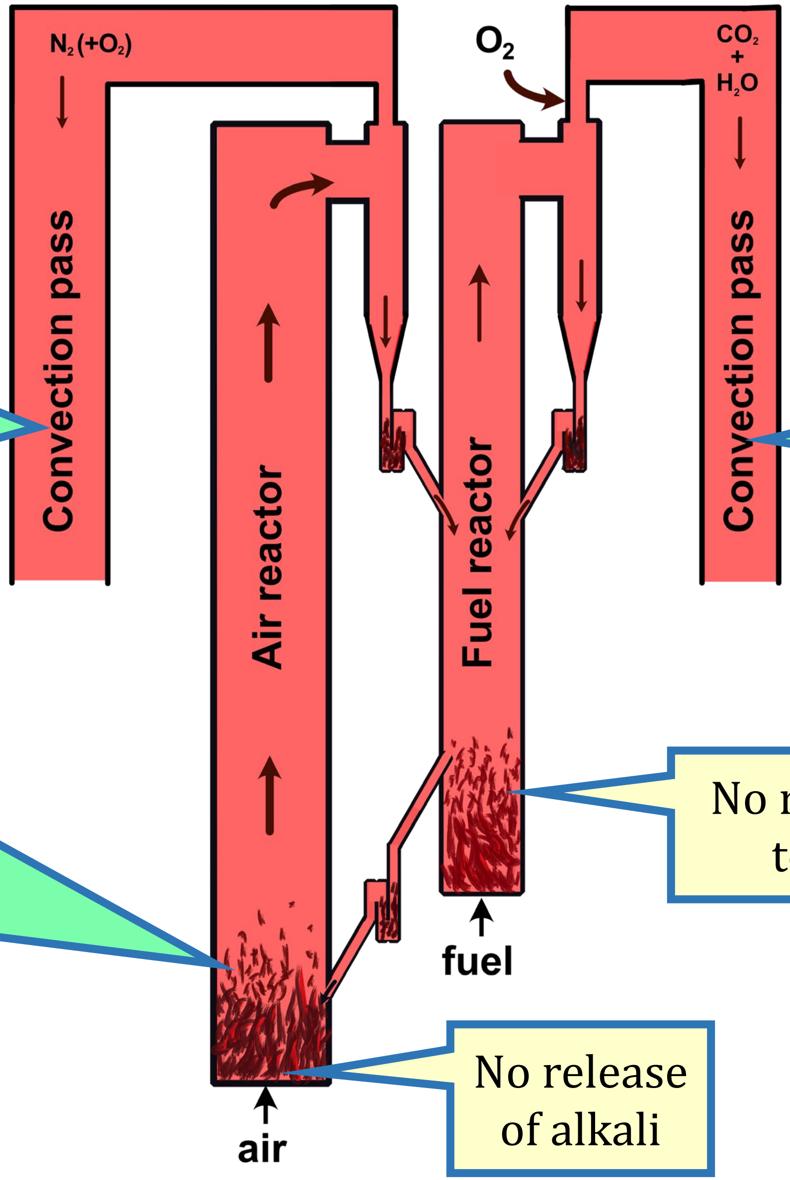
Advantage relative to normal CFB combustion?

Possibility to raise steam temperature / efficiency ?

Reduced maintenance ?

Increased availability ?

Possibility to use more difficult fuels ?




No problems

No release, alkali binds to oxygen carrier

No release of alkali

**Path 2b**

Alkali binds permanently to oxygen carrier, *but causes bed agglomeration*

No alkali in air reactor or AR convection pass.

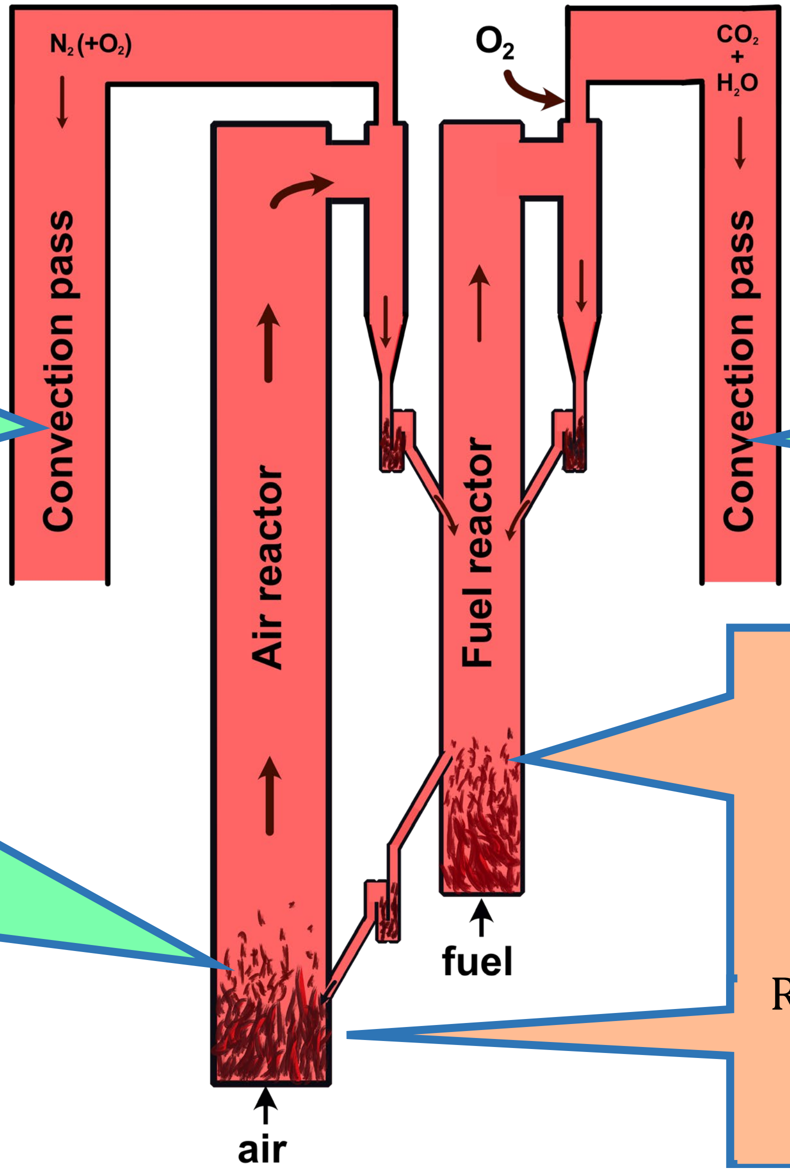
Advantage relative to normal CFB combustion?

Possibility to raise steam temperature / efficiency ?

Reduced maintenance ?

Increased availability ?

Possibility to use more difficult fuels ?



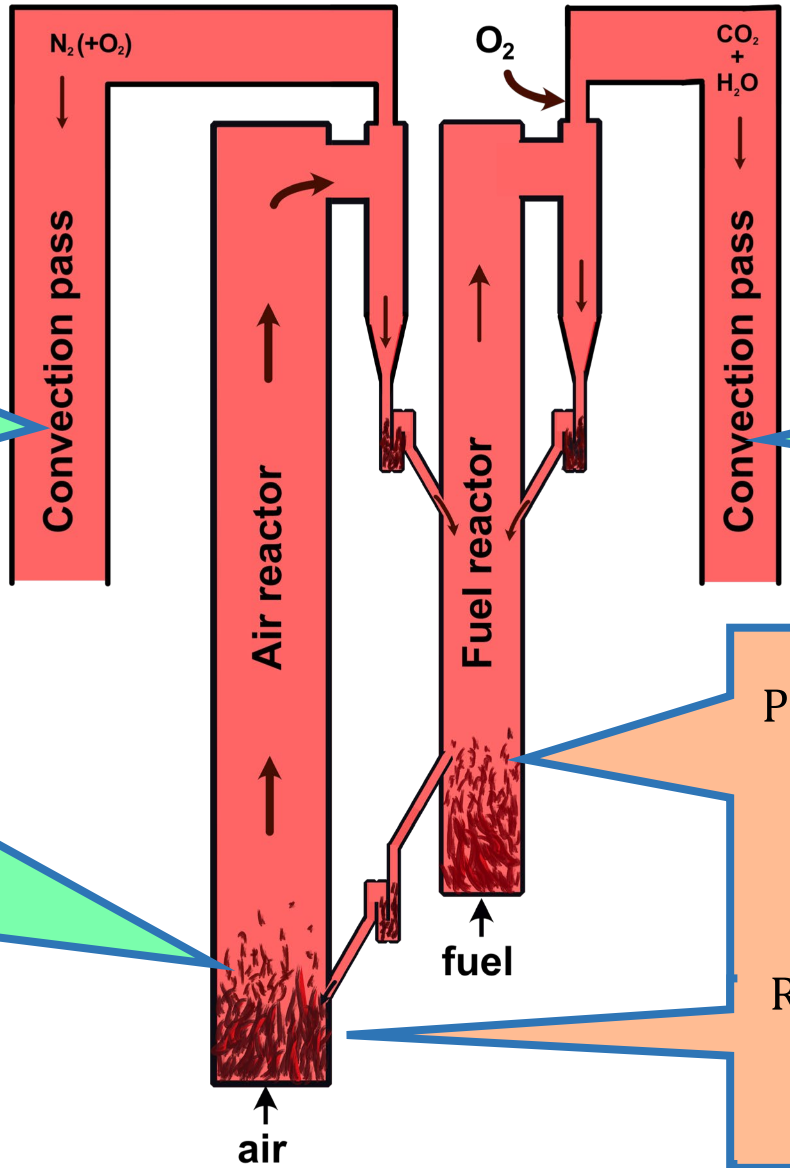

No problems

Problems with bed agglomerations

<u>Countermeasures</u>:
Other oxygen carrier
Raised turn-over of solids inventory
= ADDED COSTS!

**Path 2c**

Alkali binds permanently to oxygen carrier, *but causes loss in reactivity*




No alkali in air reactor or AR convection pass.

Advantage relative to normal CFB combustion?

Possibility to raise steam temperature / efficiency ?

Reduced maintenance ?

Increased availability ?

Possibility to use more difficult fuels ?

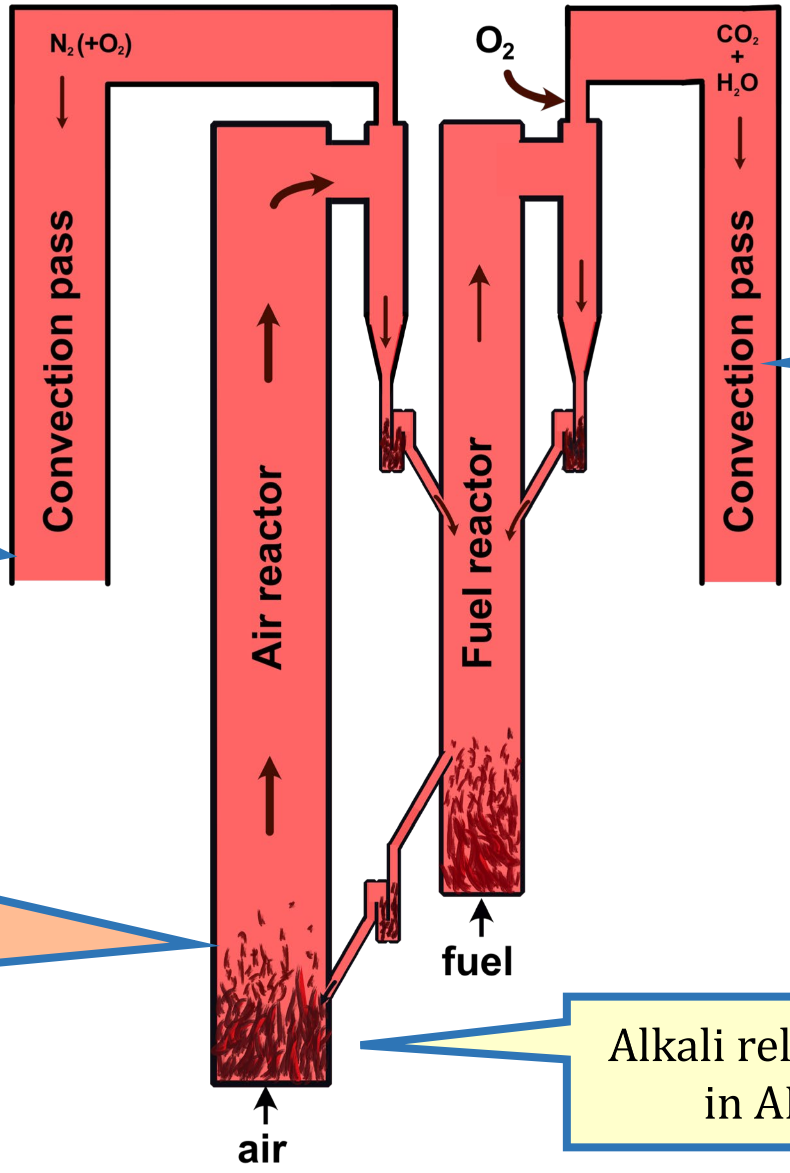
No problems

Problems with lost oxygen carrier reactivity

Countermeasures:
Other oxygen carrier
Raised turn-over of solids inventory
= ADDED COSTS!

**Path 3**

Alkali binds *non-permanently* to oxygen carrier, *release of alkali in air reactor (and fuel reactor)*



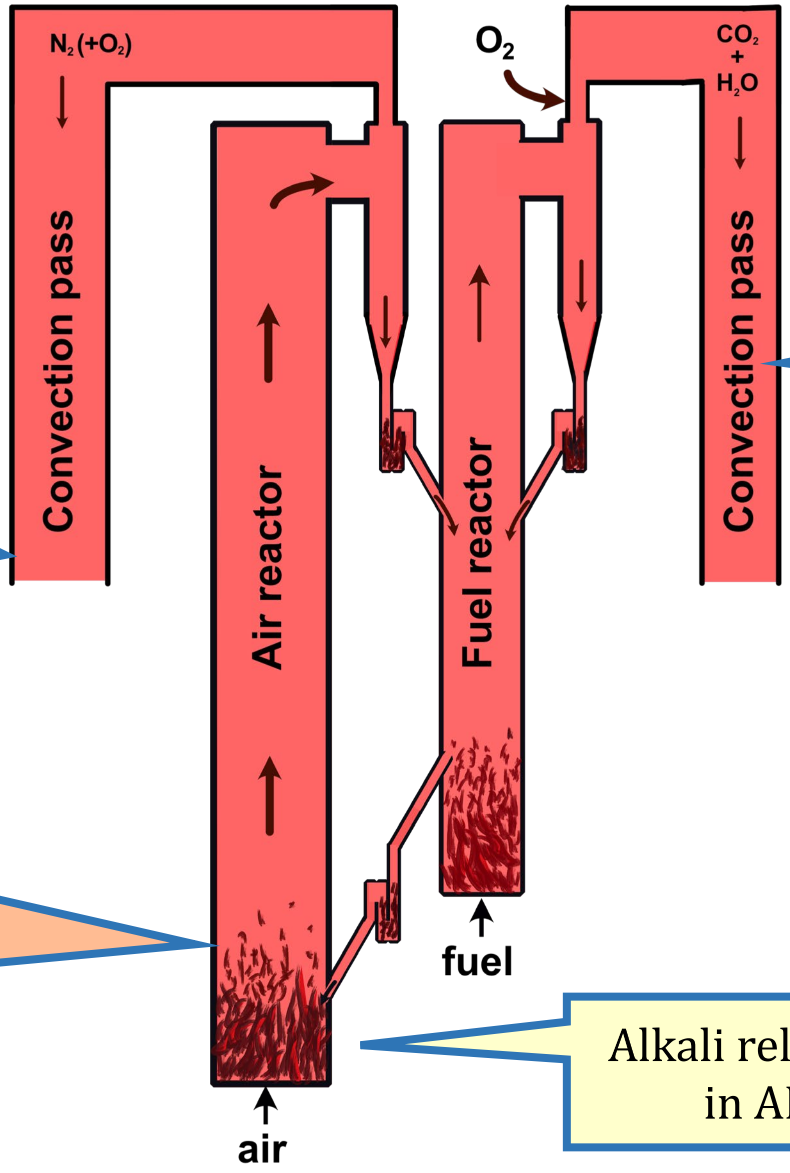

No advantage (or worse) as compared to normal CFB combustion.

No advantage (or worse) as compared to normal CFB combustion.

<u>Countermeasures</u>:
Same as normal combustion
Other oxygen carrier

Alkali released in AR

**Path 4**
Alkali forms ash particles that *releases alkali in air reactor (and fuel reactor)*




No advantage (or worse) as compared to normal CFB combustion.

No advantage (or worse) as compared to normal CFB combustion.

Countermeasures:
Same as normal combustion
Other oxygen carrier

Alkali released in AR

Path 1. Released in FR, and leaves with FR gas (as gas or particles)

Path 2. Binds to permanently to OC, without causing problems

Path 2b. Binds to OC, but causes bed agglomeration.

Path 2c. Binds to OC, and causes loss of reactivity.

Path 3. Binds loosely to OC, and causes release of AC in AR.

Path 6. AC forms ash particles that follow particle flow to AR.

Q1: Is alkali released from FR, or binds to oxygen carrier ?
- For which oxygen carrier ?
- Effect of e.g. T ?
- Capacity to bind ?
- Effect of oversaturation ?

Q2: Bed agglomeration, conditions ?

Q3: Loss of reactivity, conditions ?

Q4: Release in AR, conditions ?
- Via OC ?
- Via ash particle formed ?

**What paths are preferred ?**
**For which fuels ?**

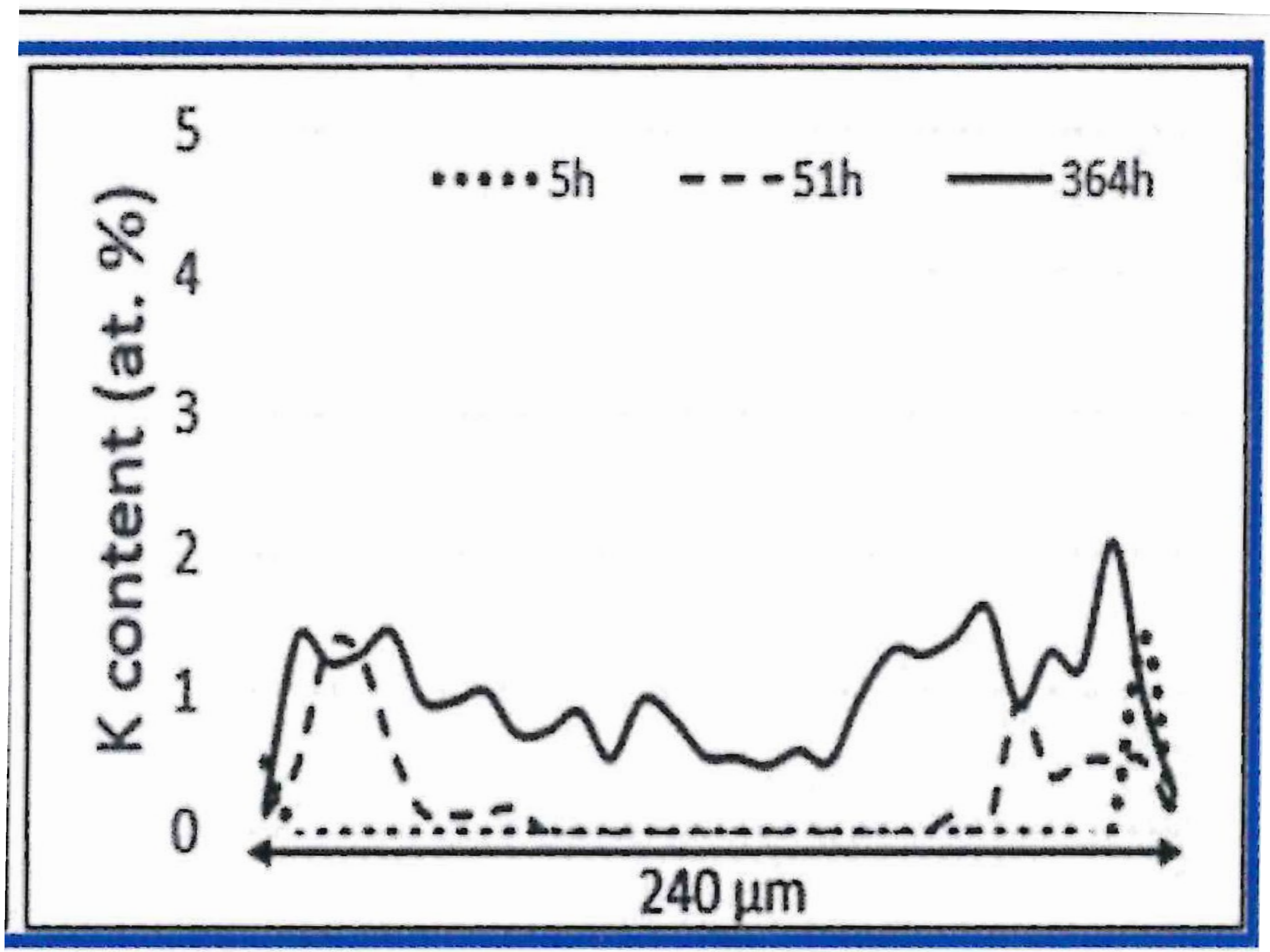
**Challenges**

1. Complex environment
2. Complex chemistry
3. Alkali difficult to measure
4. Relevance of lab / small scale pilot measurements

***What methodologies will helpful to answer these questions ?***

Operation of ilmenite in industrial scale in Oxygen Carrier Aided Combustion, shows K is present in the interior of the particle,

[Corcoran, A., Knutsson, P., Lind, F., and Thunman, H., Mechanism for Migration and Layer Growth of Biomass Ash on Ilmenite Used for Oxygen Carrier Aided Combustion *Energy and Fuels* **32**(8), (2018) 8845-8885 ]



Path 1. Released in FR, and leaves with FR gas (as gas or particles)

Path 2a. Binds to permanently to OC, without causing problems

Path 2b. Binds to OC, but causes bed agglomeration.

Path 2c. Binds to OC, and causes loss of reactivity.

Path 3. Binds to OC, and causes release of AC in AR.

Path 6. AC forms ash particles that follow particle flow to AR.

Q1: Is AC released in FR, or binds to OC, or forms ash?

- 1a For which OC ?
- 1b Effect of e.g. T ?
- 1c Capacity to bind
- 1d Effect of oversaturation?

Q2: Bed agglomeration, conditions ?

Q3: Loss of reactivity, conditions ?

Q4: Release in AR, conditions ?

- 4a Via OC ?
- 4b Via ash particle formed ?

**Difficult question:**
**What paths are preferred ?**
**For which fuels ?**

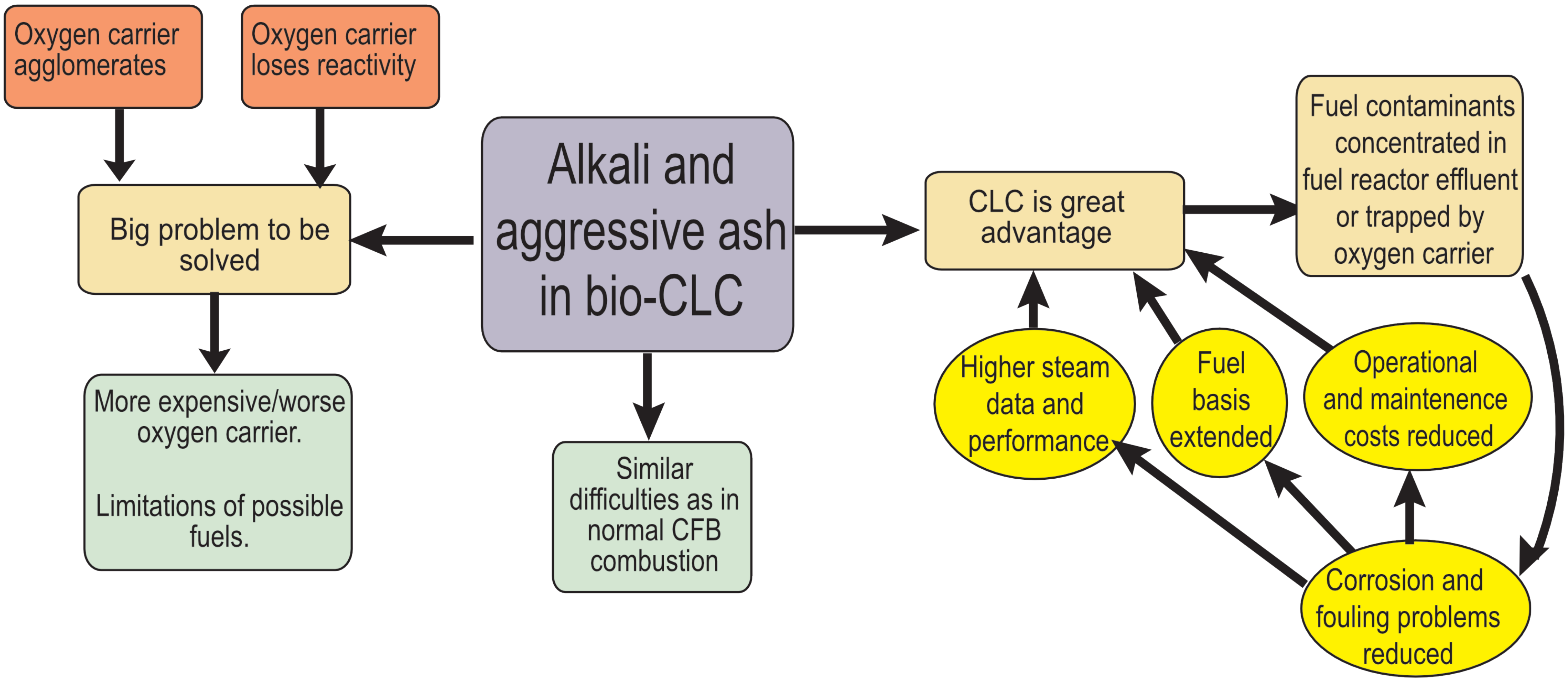
**Tools**

1. Literature, experiences from biomass combustion in fluidized-beds, experiences from Oxygen Carrier Aided Combustion in large CFB boilers

2. Laboratory experiments exposing oxygen carrier to ash components in fixed and fluidized beds.

3. Pilot experiments, measurements in outgoing FR and AR streams. Analysis of spent material. Effect of operational conditions: fuel, temperature, circulation, steam addition, oxygen carrier

4. Thermochemical modelling


Oxygen carrier agglomerates
Oxygen carrier loses reactivity
Big problem to be solved
More expensive/worse oxygen carrier.
Limitations of possible fuels.
Alkali and aggressive ash in bio-CLC
Similar difficulties as in normal CFB combustion
CLC is great advantage
Fuel contaminants concentrated in fuel reactor effluent or trapped by oxygen carrier
Higher steam data and performance
Fuel basis extended
Operational and maintenence costs reduced
Corrosion and fouling problems reduced


**JUNE 14-17, 2022,**

(delayed due to pandemia)

http://negativeco2emissions2020.com/