Chemical Looping Combustion - power generation and H_2 production with CO_2 capture

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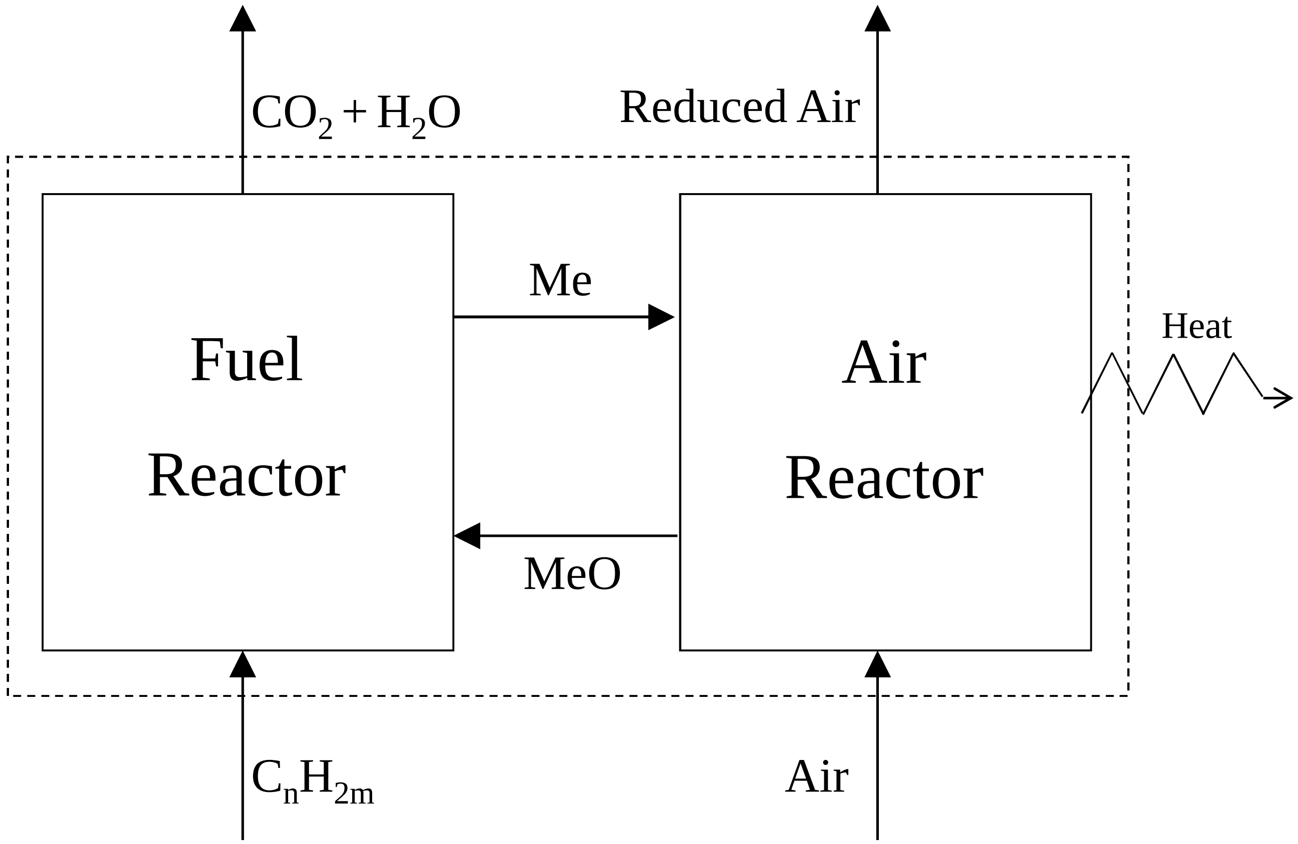
What is CLC?

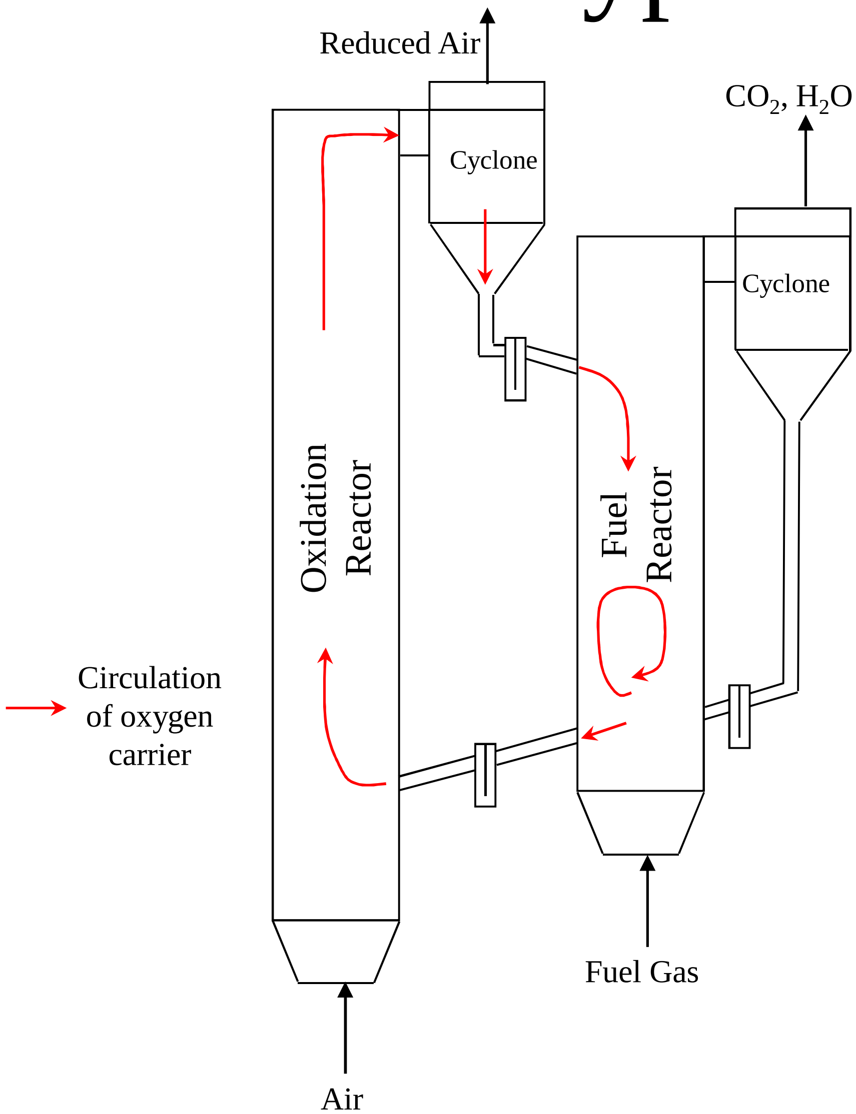


$CO_2 + H_2O$
Reduced Air
Me
Fuel
Reactor
Air
Reactor
Heat
MeO
C_nH_{2m}
Air

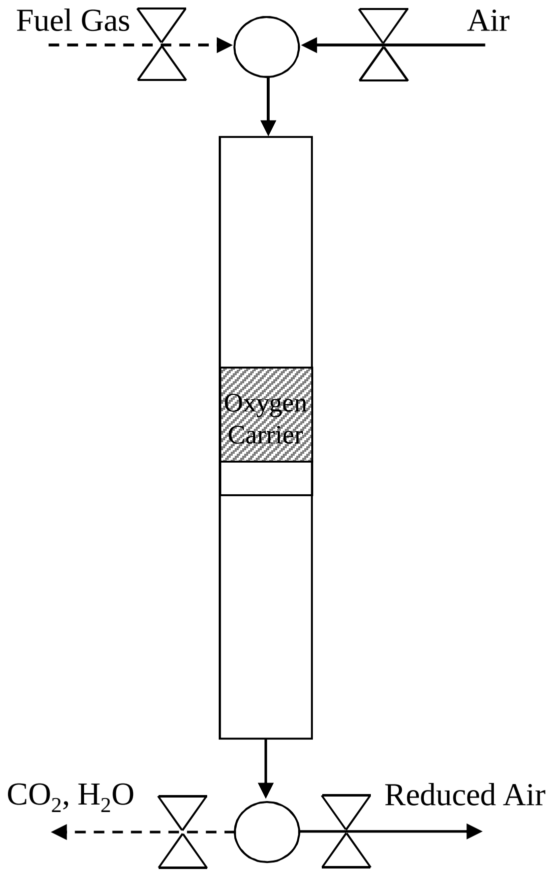
What are the advantages?

- No sorbent required
- No ASU required
- High fuel conversions (≈ 100 %) achievable
- Applicable for range of fuel types

A typical CLC plant

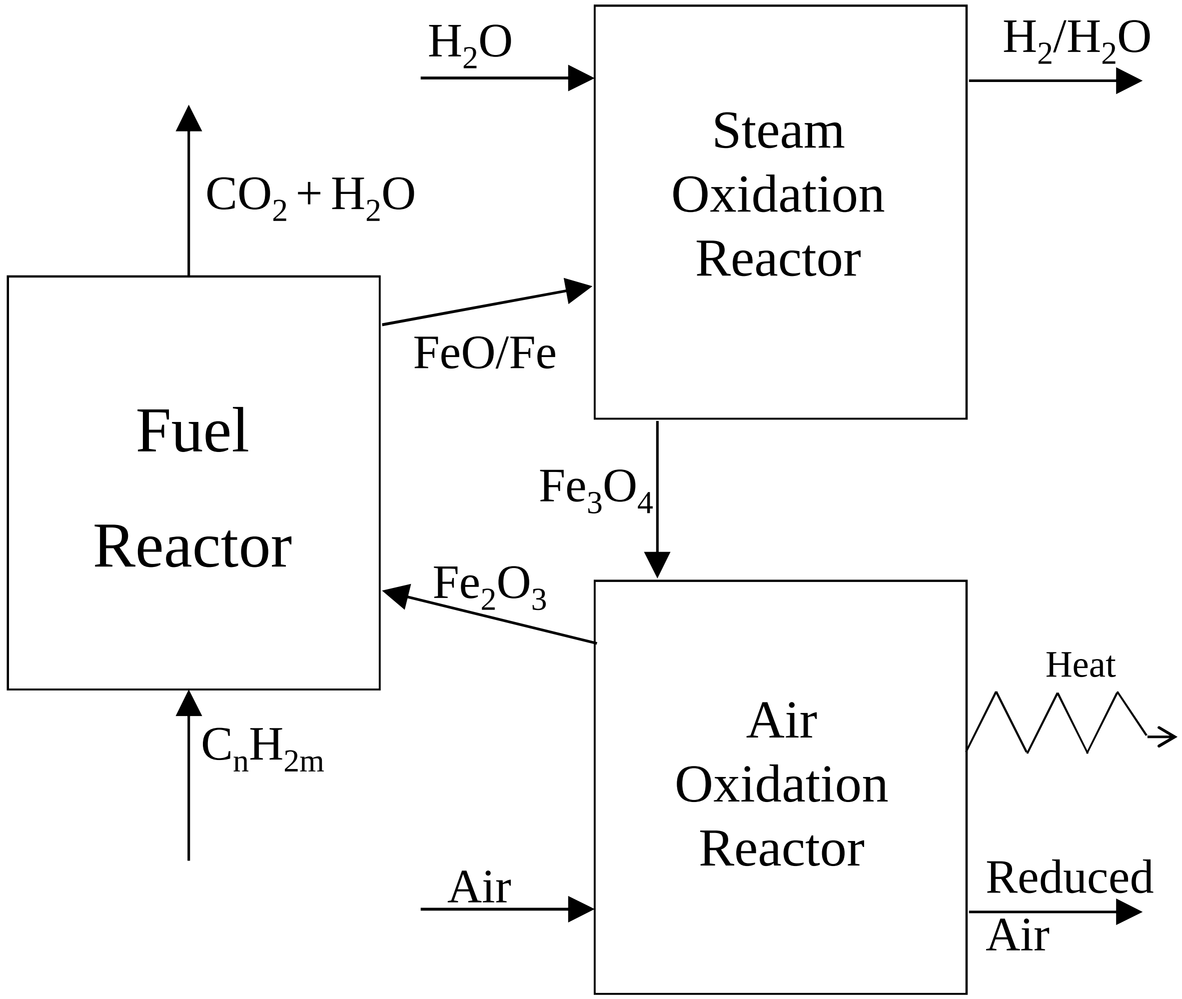


Dual Circulating Fluidised Bed



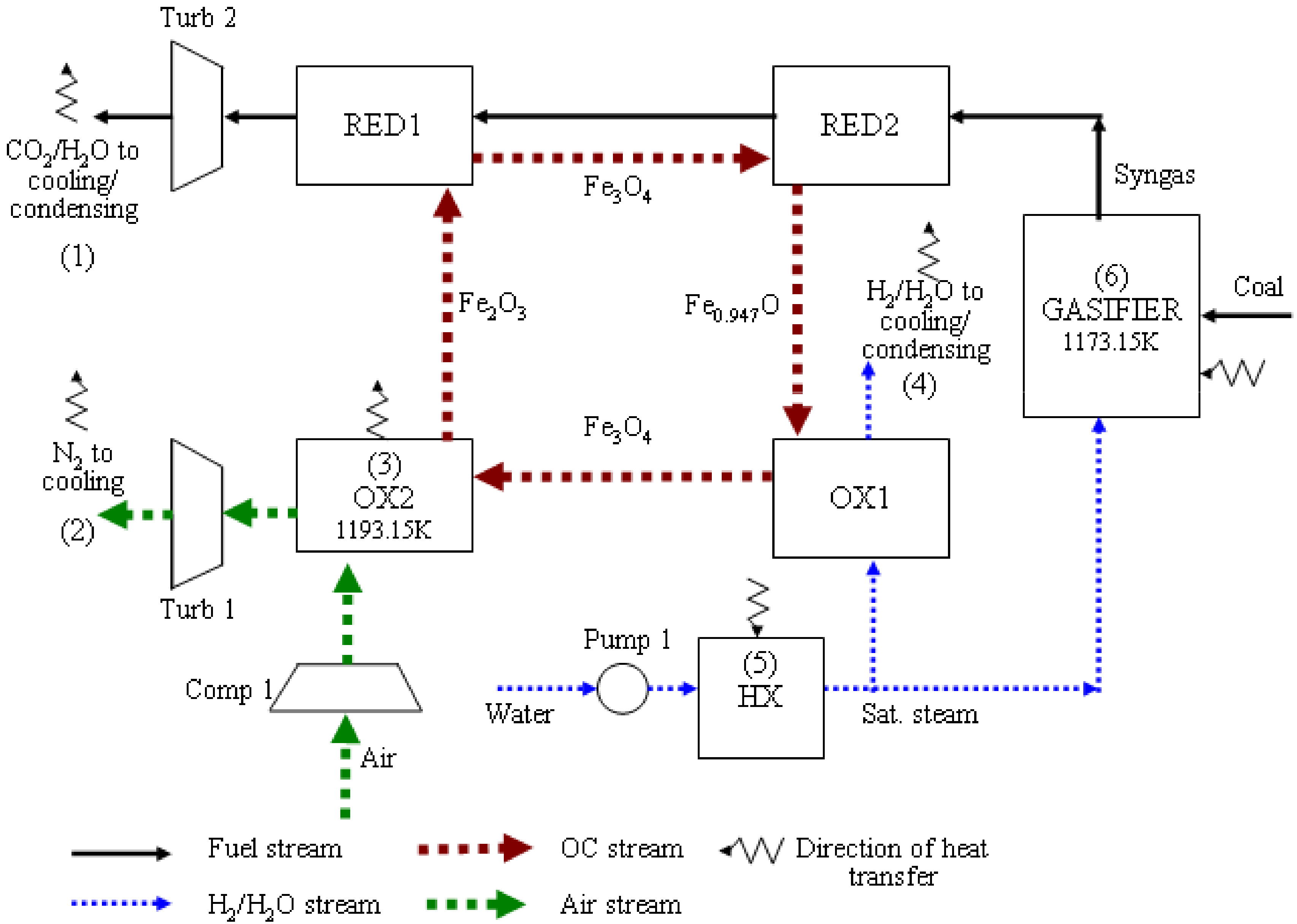
Packed Bed

CLC with H_2 production and Power Generation



Flowsheeting of a CLC Process with H_2 Production and Power Generation

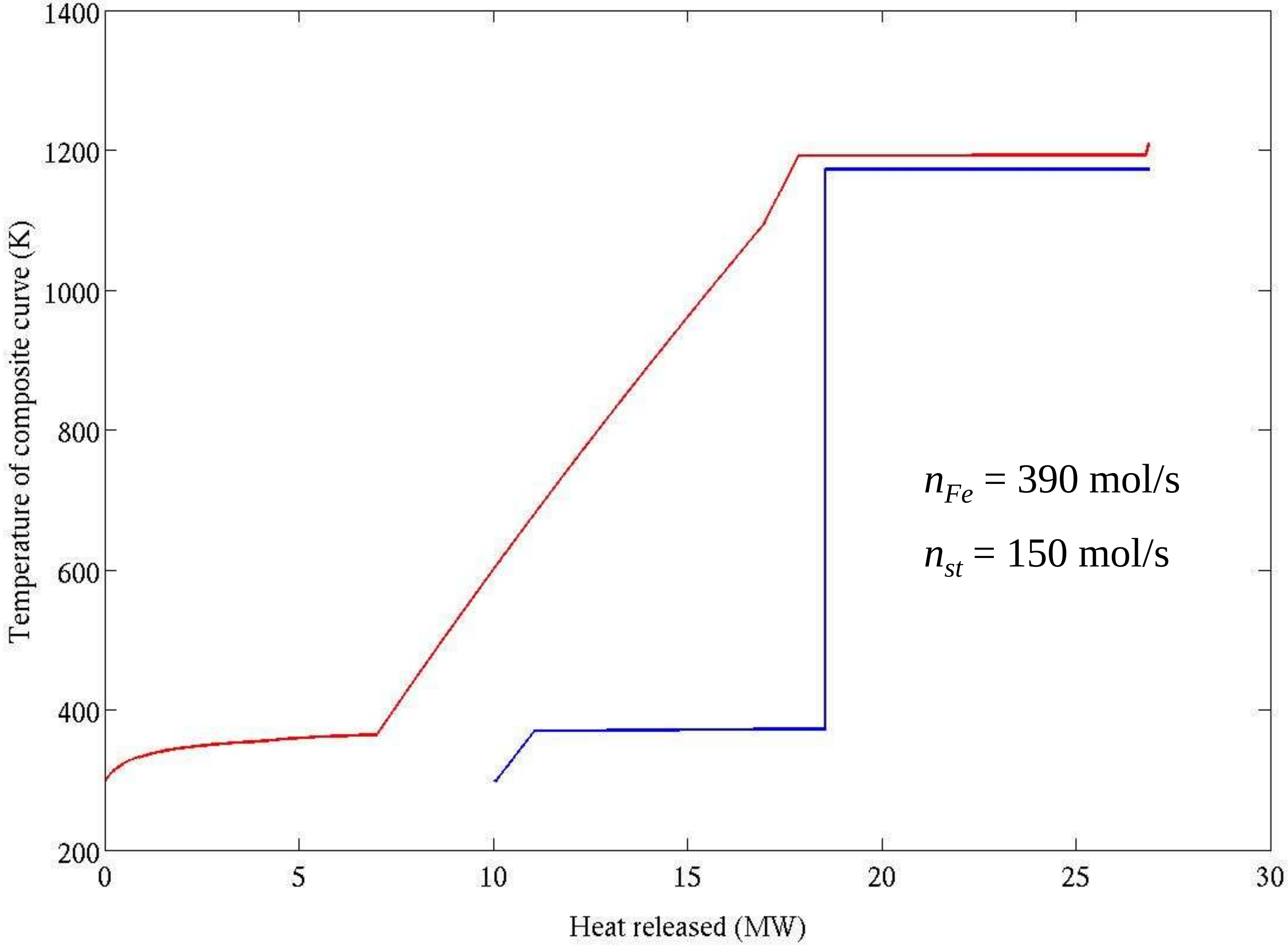
Process Flowsheet



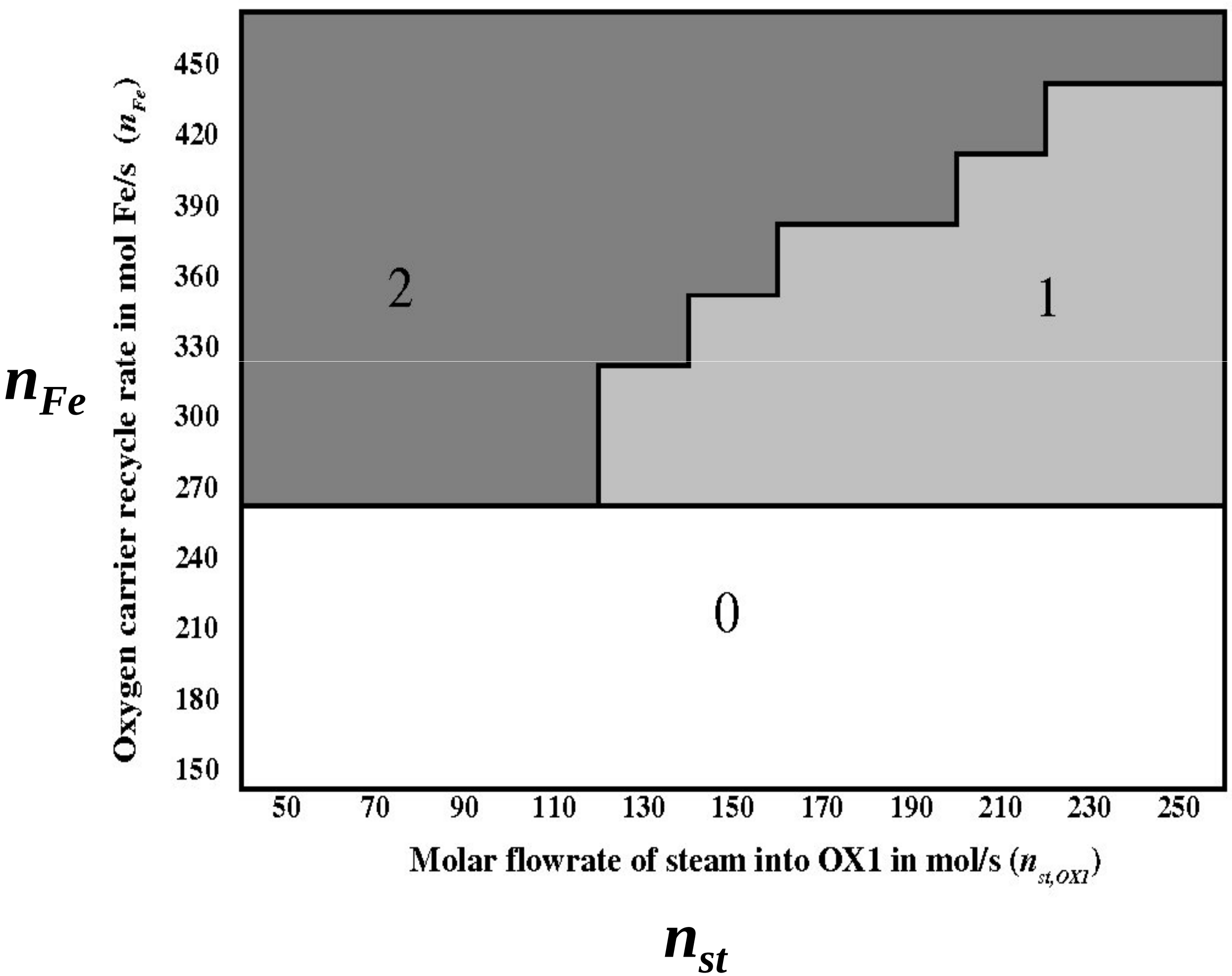
Solving of Flowsheet

- Modelled in MATLAB
  - Thermodynamic data from NASA-Glenn database
  - Reactions solved by Gibbs Energy minimisation
- Two key system variables
  - Iron oxide circulation rate n_{Fe}
  - Steam flowrate into OX1 n_{st}

Heat Integration



Suitable Operating Regime



0 = Unsuitable

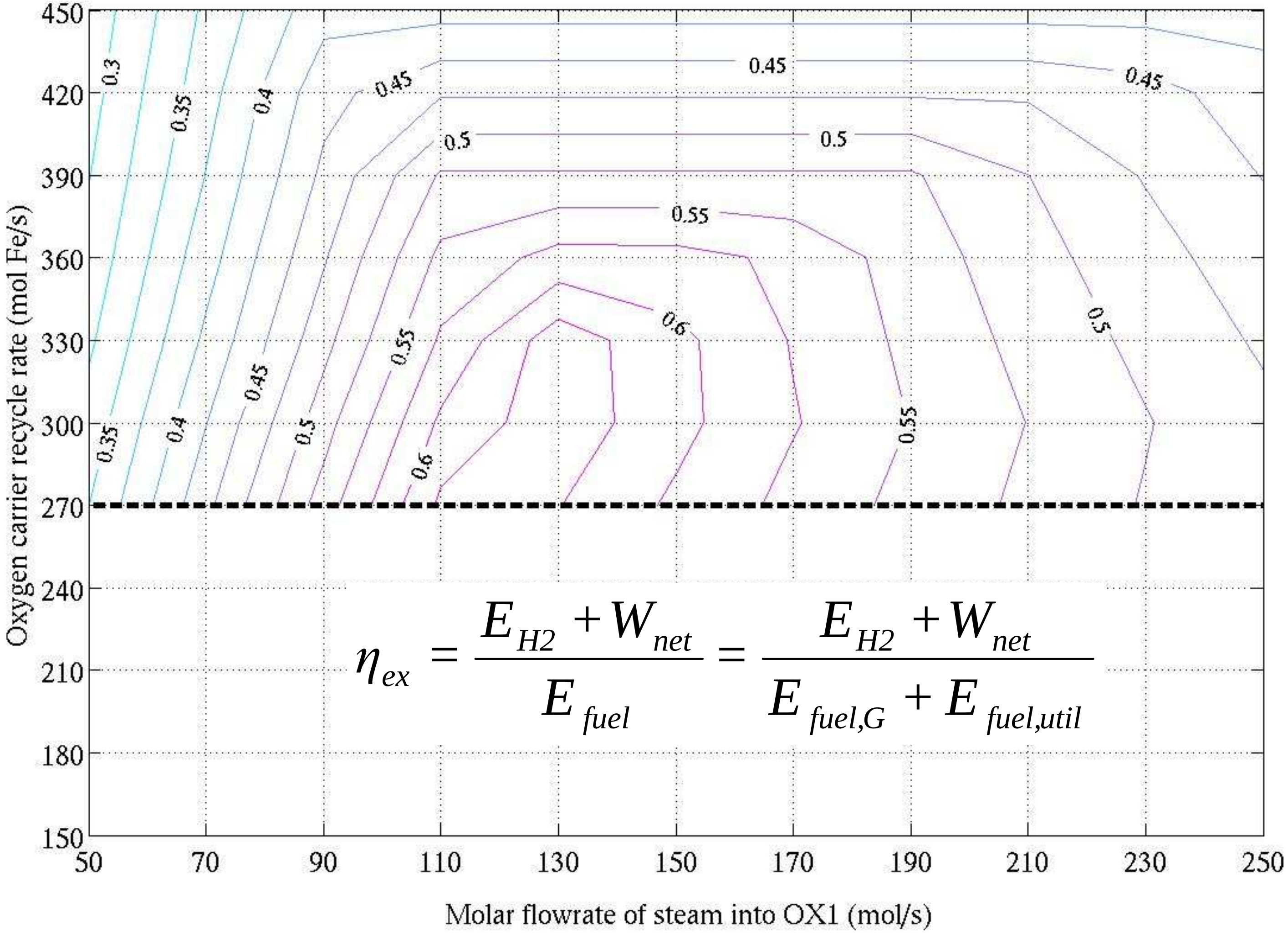
1 = Suitable, external heat required

2 = Suitable, fully heat-integrated

Operating Criteria

- H_2 stream ≥ 95% pure.
- Conversion of fuel to CO_2 and H_2O ≥ 95%.
- CO in the produced H_2 stream < 50 ppm.

Exergetic Efficiency (η_{ex})



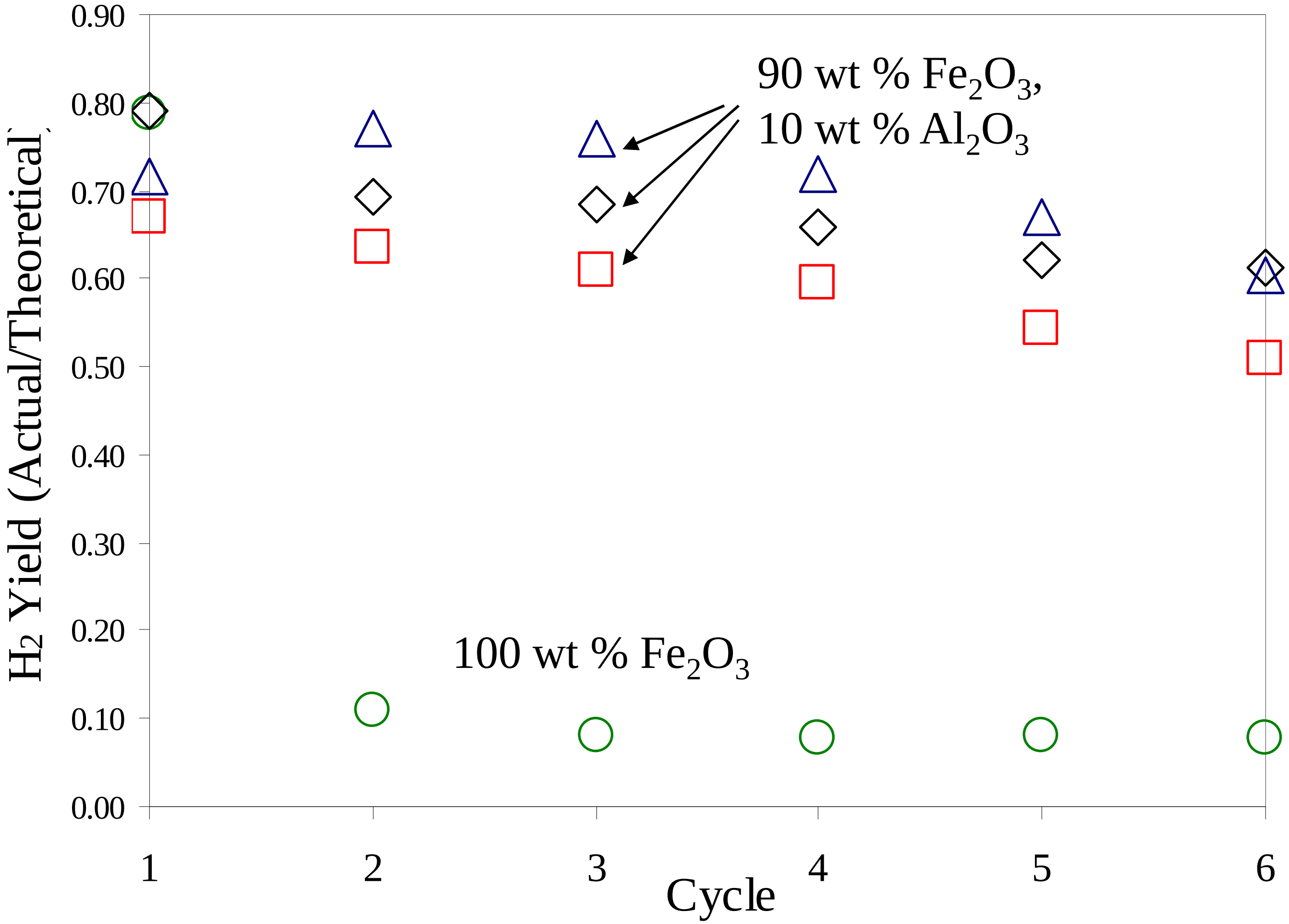
n_{Fe}

n_{st}

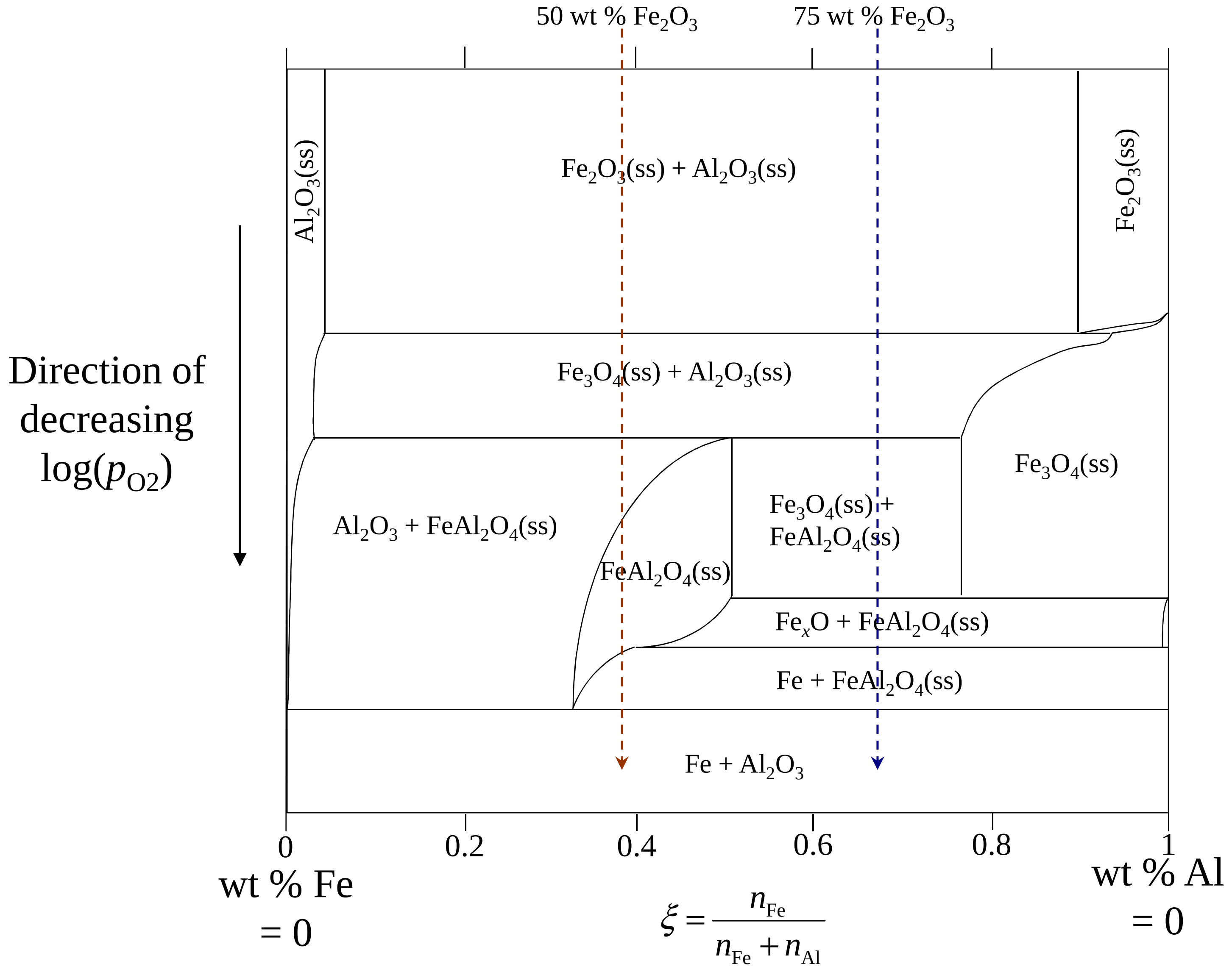
$$\eta_{ex} = \frac{E_{H2} + W_{net}}{E_{fuel}} = \frac{E_{H2} + W_{net}}{E_{fuel,G} + E_{fuel,util}}$$

Enhancing oxygen carrier performance with Al_2O_3 support

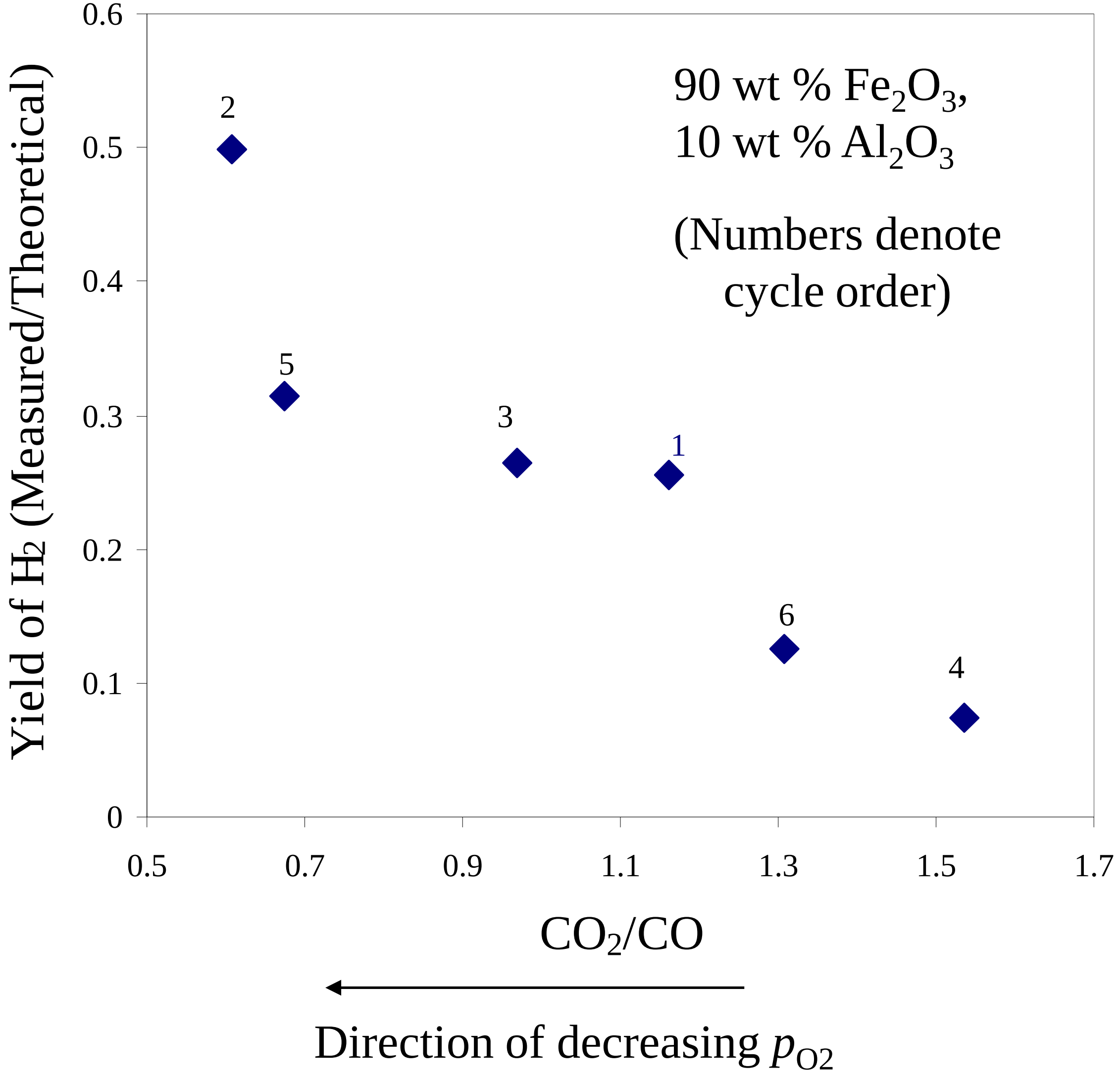
Al_2O_3 as a support material



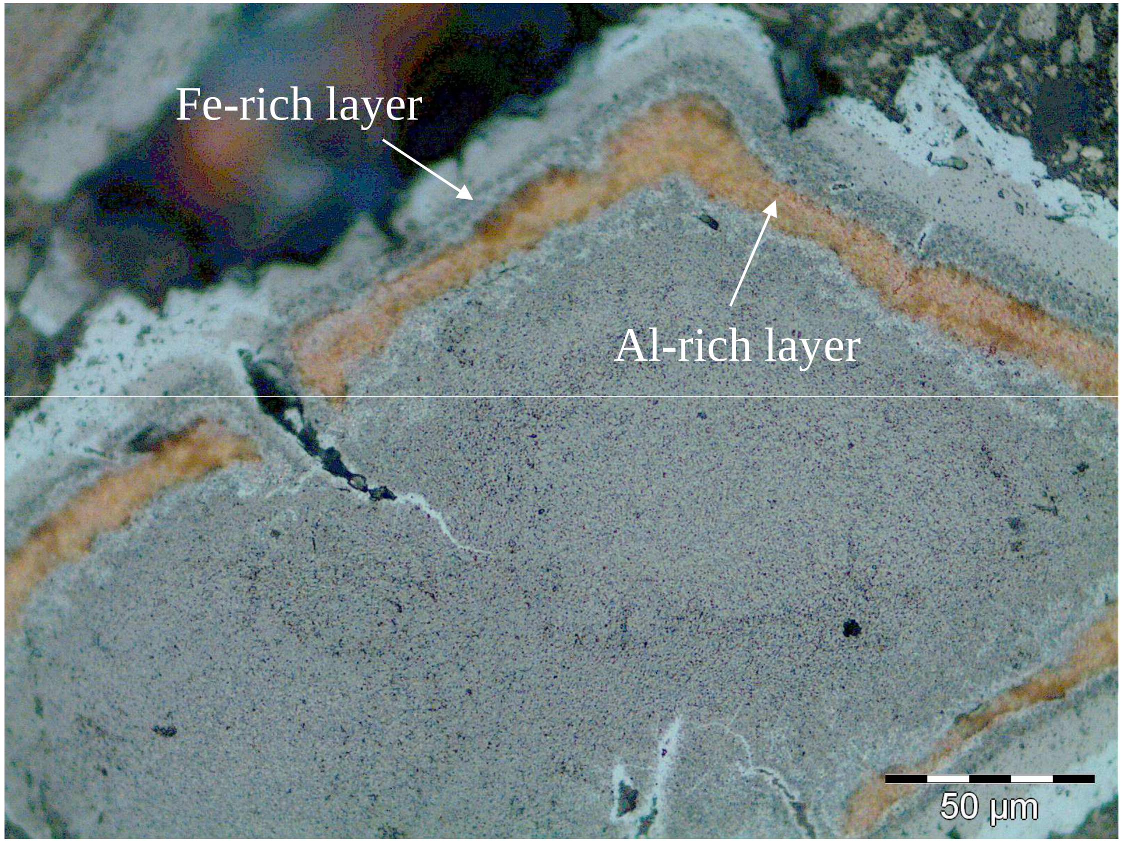
Fe-Al-O phase diagram



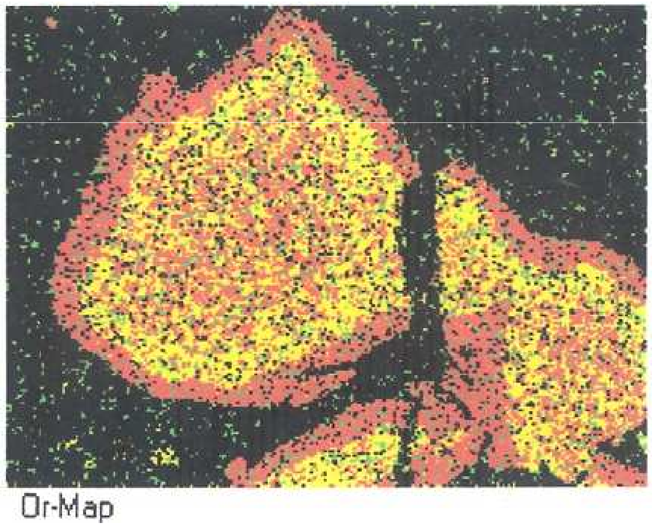
Effect of Fe-Al-O phase equilibrium on H_2 production



Oxygen carrier particle after cycling



75 wt% Fe_2O_3, 25 wt% Al_2O_3 after 20 cycles, sectioned



EDXS map

(red = Fe

yellow = Al)

Conclusions

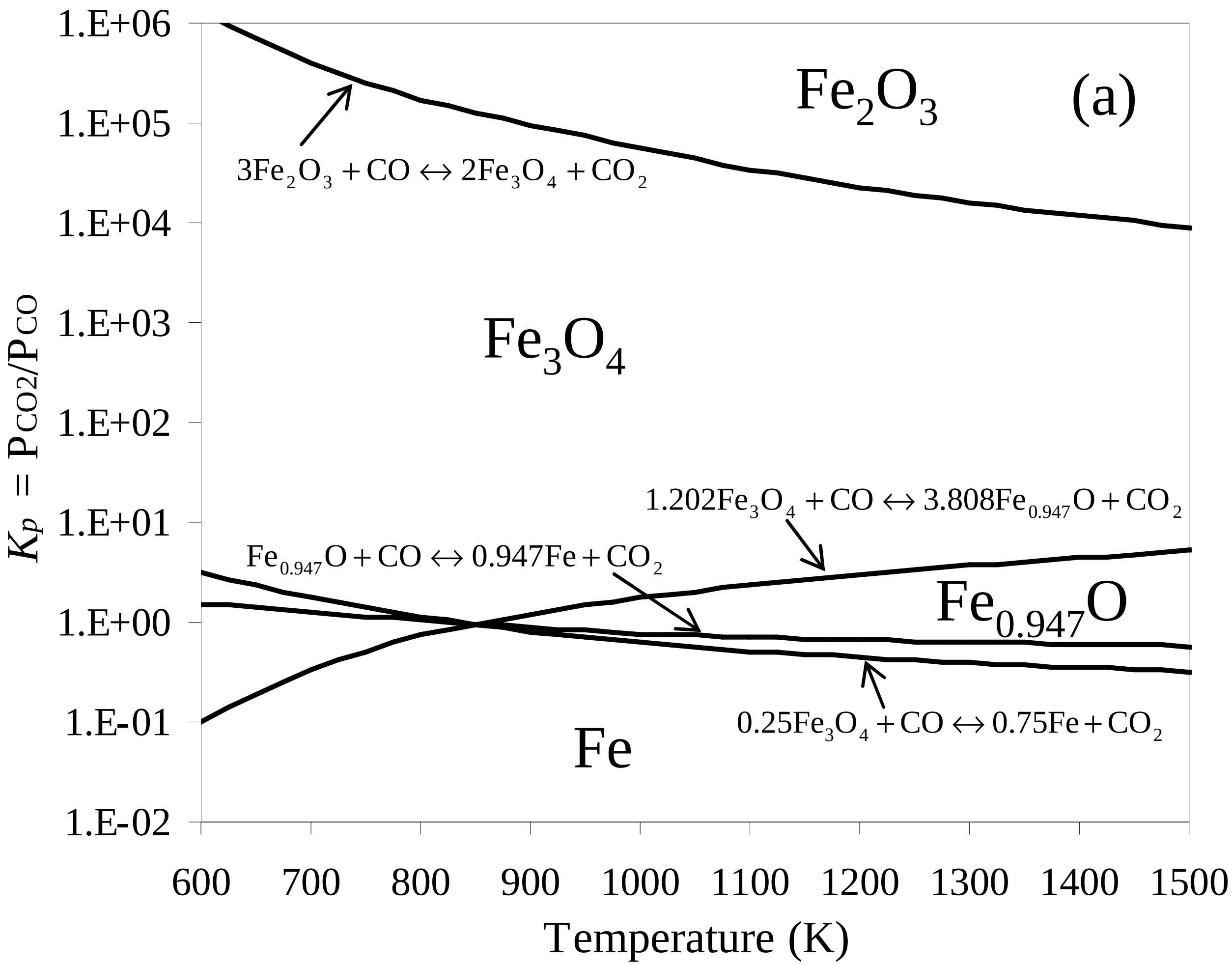
- CLC has high potential for highly efficient CO_2 capture with both power generation and H_2 production
- Can be optimised towards producing electrical power/H_2
- Oxygen carrier support material (such as Al_2O_3) essential for long-term performance
  - Interaction between reactive and support material must be fully understood.

Related Publications

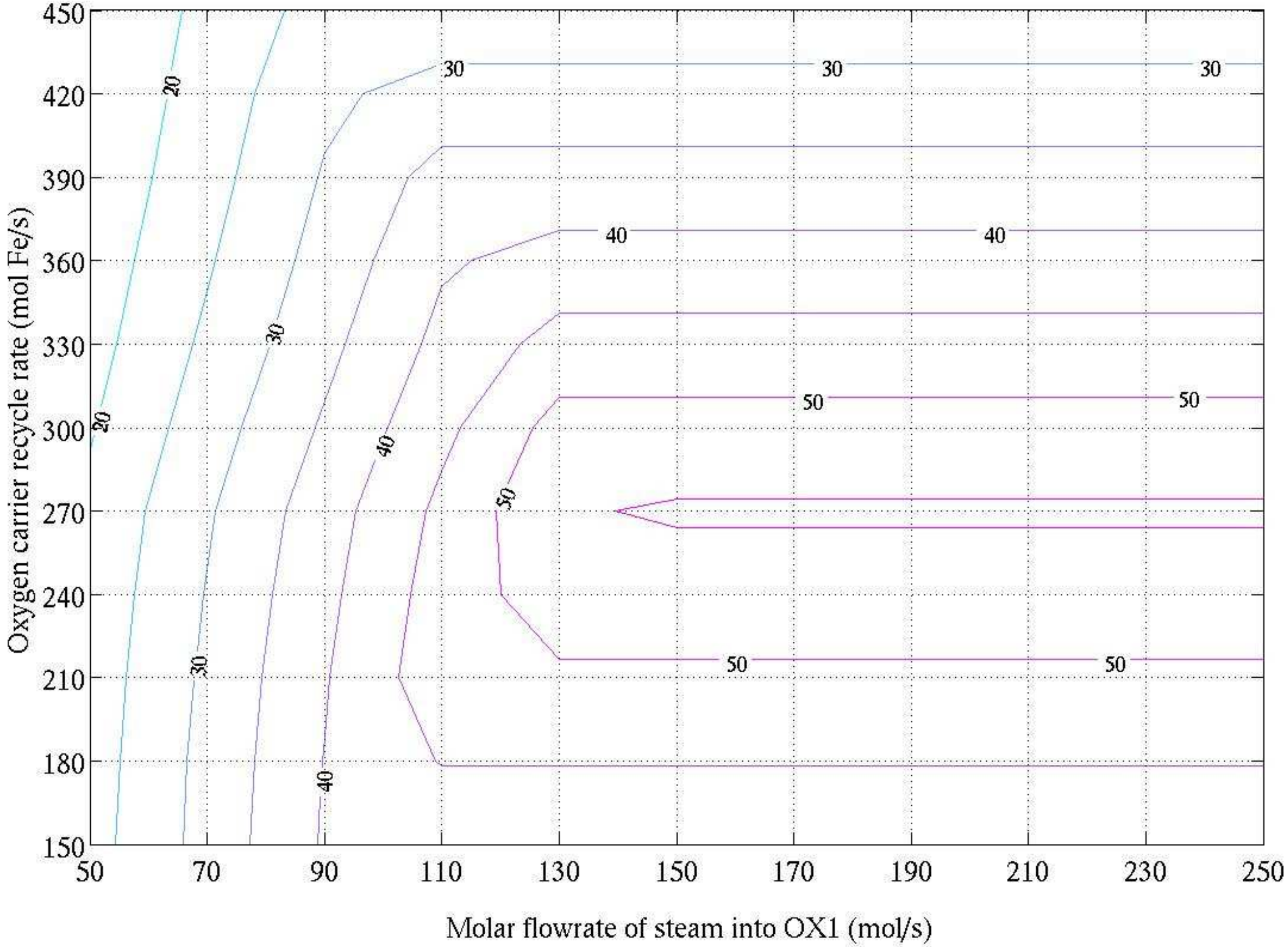
- J.P.E. Cleeton, S.A. Scott & J.S. Dennis. Interaction between Fe-based oxygen carriers and volatile hydrocarbons during Chemical Looping. Submitted to Appl Energ (2011)
- P.R. Kidambi, J.P.E. Cleeton, J.S. Dennis, S.A. Scott & C.D. Bohn, The interaction of iron oxide with alumina within a composite oxygen carrier during the production of hydrogen by chemical looping. Submitted to Energy Fuels (2011)
- C.D. Bohn, J.P.E. Cleeton., C.R. Müller, J.F. Davidson, A.N. Hayhurst, S.A. Scott & J.S. Dennis, The kinetics of the reduction of iron oxide by carbon monoxide mixed with carbon dioxide. AIChE J. 56(4) (2010) pp 1016-1029.
- J.P.E. Cleeton, C.D. Bohn, C.R. Müller, J.S. Dennis & S.A. Scott, Different Methods of Manufacturing Fe-Based Oxygen Carrier Particles for Reforming Via Chemical Looping, and Their Effect on Performance, Proceedings of 20th International Conference on Fluidised Bed Combustion (4) (2010) pp 505-511
- C.D. Bohn, J.P.E. Cleeton, C.R. Muller, S.A. Scott & J.S. Dennis. Stabilising iron oxide used in cycles of reduction and oxidation for hydrogen production. Energy Fuels. 24(7) (2010) pp 4025–4033
- J.P.E. Cleeton, C.D. Bohn, C.R. Müller, J.S. Dennis & S.A. Scott, Clean hydrogen production and electricity from coal via chemical looping: Identifying a suitable operating regime, Int J Hydrogen Energ 34(1) (2009) pp 1-12

Thank you
Any questions?

Phase diagram



Hydrogen Production



n_{Fe}

n_{st}

Units denote mol H_2 /s/kg fuel