Chemical Looping Combustion for inherent CO_2 capture in a coal-based IGCC power plant

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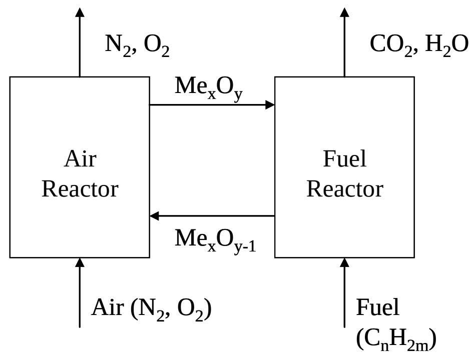
Objectives

- Evaluate CLC using syngas as fuel
  - Effect of fuel
  - Effect of operating conditions
- Use CLC for CO_2-capture in a coal-based IGCC power plant using different gasification technologies

What is CLC

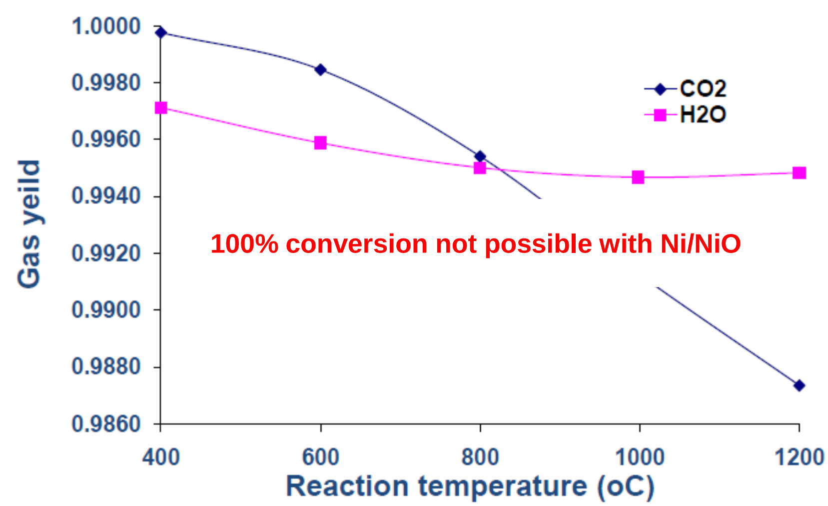
- Indirect combustion process
- Produces a high purity CO_2 stream
- Oxygen supplied by an oxygen carrier
- Possible OC
  - Ni
  - Cu
  - Fe
  - Mn



Reactions

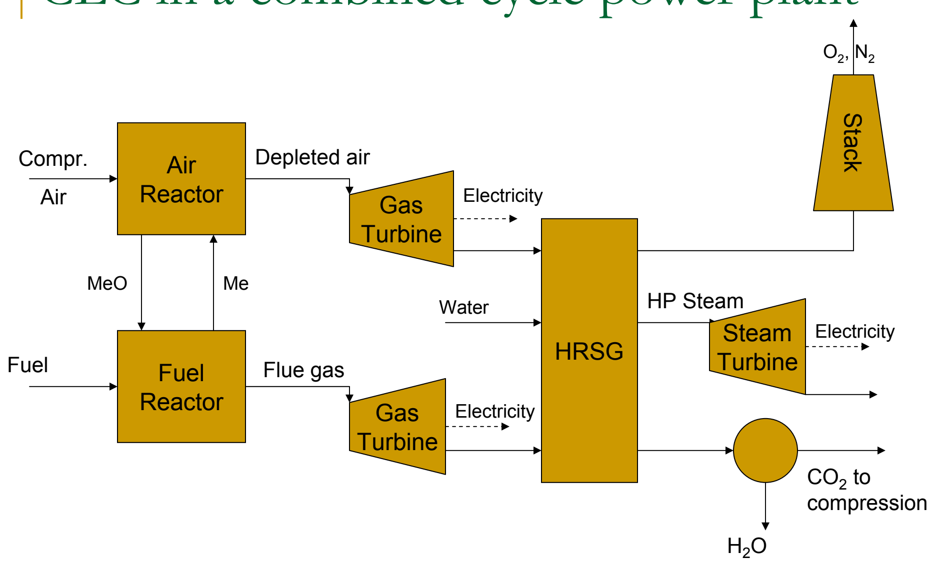
- $Ni + \frac{1}{2} O_2 \Leftrightarrow NiO$
  $\Delta H = -234$ kJ/mol
- $CH_4 + 4NiO \Leftrightarrow CO_2 + 2H_2O + 4Ni$
  $\Delta H = 134$ kJ/mol
- $CO + NiO \Leftrightarrow CO_2 + Ni$
  $\Delta H = -43.3$ kJ/mol
- $H_2 + NiO \Leftrightarrow H_2O + Ni$
  $\Delta H = -2.1$kJ/mol
- $xCO + yH_2 + zCH_4 + (x+y+4z)NiO \Leftrightarrow (x+z)CO_2 + (y+2z)H_2O + (x+y+4z)Ni$

Conversion decreases with temperature



$$\gamma_{CO} = \frac{p_{CO2}}{p_{CO2} + p_{CO}} \qquad \gamma_{h2} = \frac{p_{H2O}}{p_{H2O} + p_{H2}}$$

CLC in a combined cycle power plant



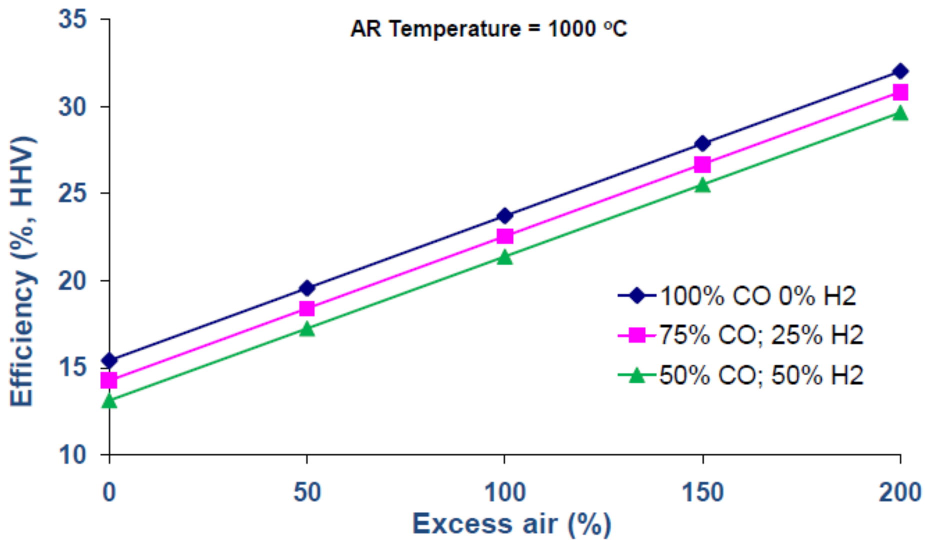
CLC model assumptions

- Fuel
  - 100% CO
  - 75% CO, 25%H_2
  - 50%CO, 50%H_2
- Air reactor (AR) – isothermal, 20 bar
  - 1000°C, 1100°C, 1200°C
- Fuel reactor (FR) – adiabatic, 20 bar
- Stoichiometric MeO
- Air-fuel ratio
  - Stoichiometric – 3*Stoicihometric
- Gas turbine
  - No special changes required for depleted air or CO_2/H_2O expansion
- Steam cycle
  - Heat rate – 8,740 kJ/kWh

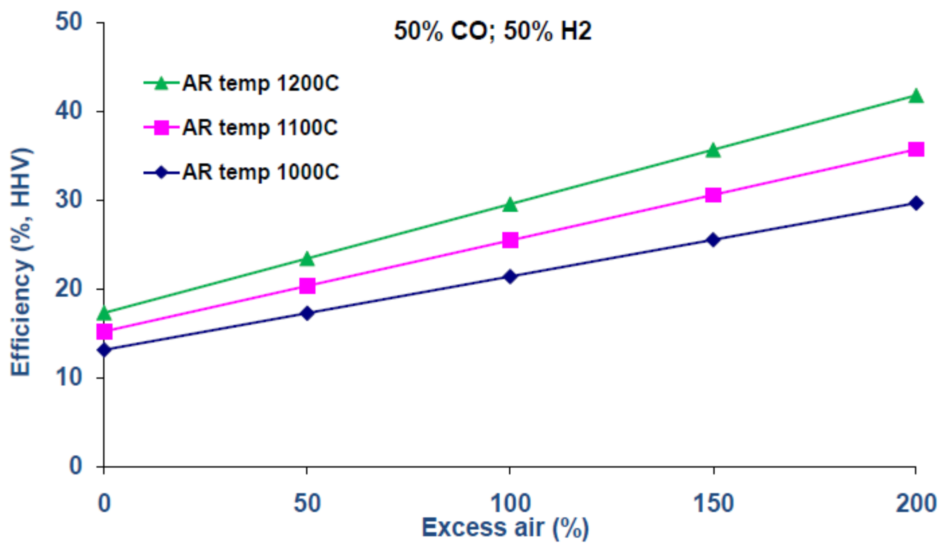
CO_2 purity

Temperature	100% CO	75% CO, 25% H2	50% CO, 50% H2
1000 °C	99.1	99.0	98.8
1100 °C	99.0	[illegible]	98.7
1200 °C	98.9	98.8	98.6

Efficiency increases with CO%

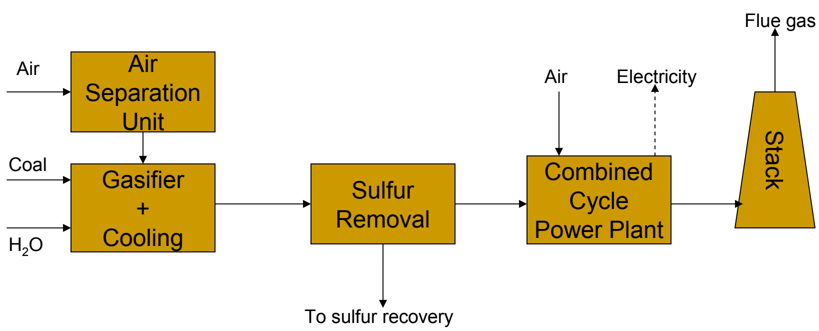


Efficiency increases with temperature

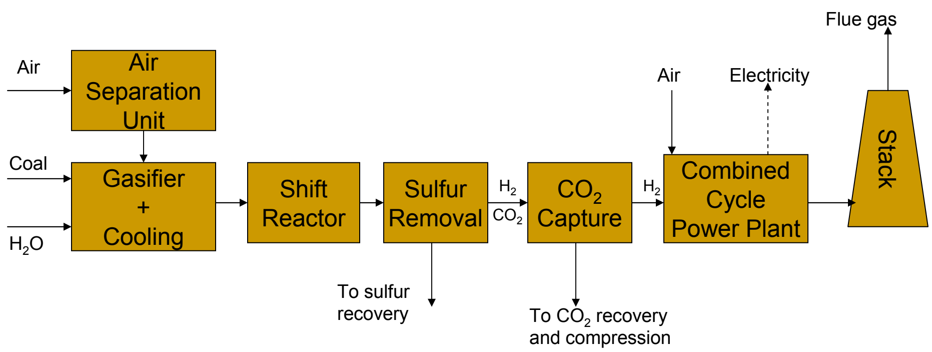


Application to IGCC

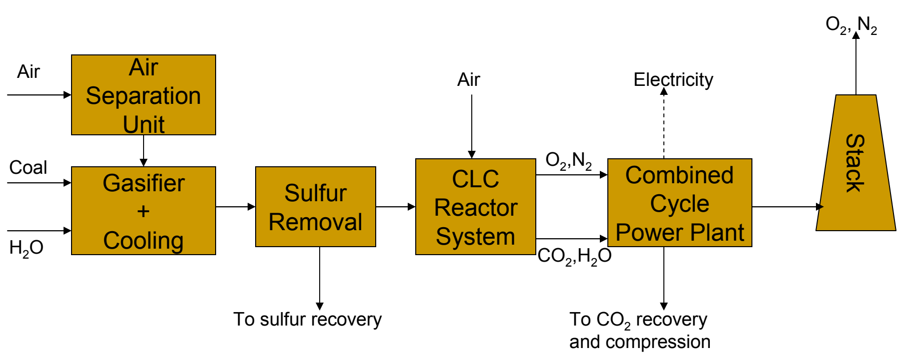
IGCC without CCS



IGCC with physical absorption CCS



IGCC with CLC

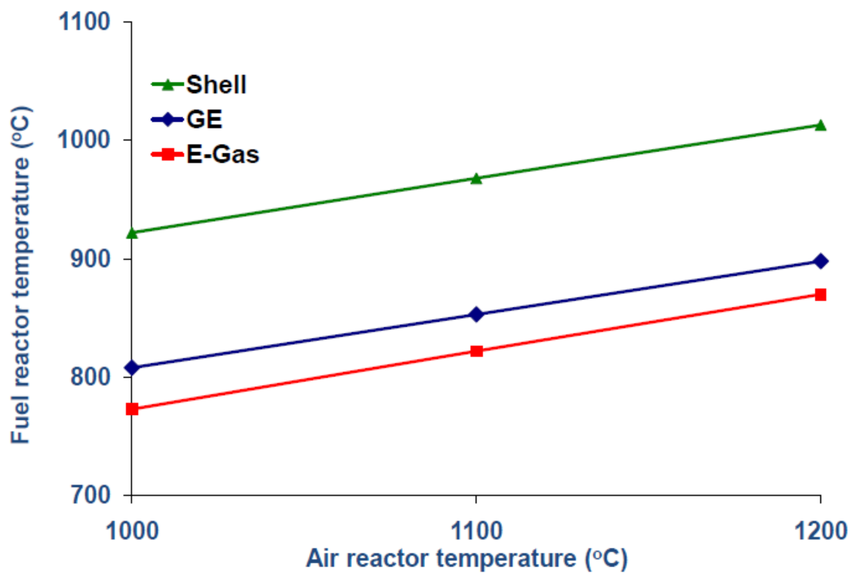


Clean syngas from different gasifiers*

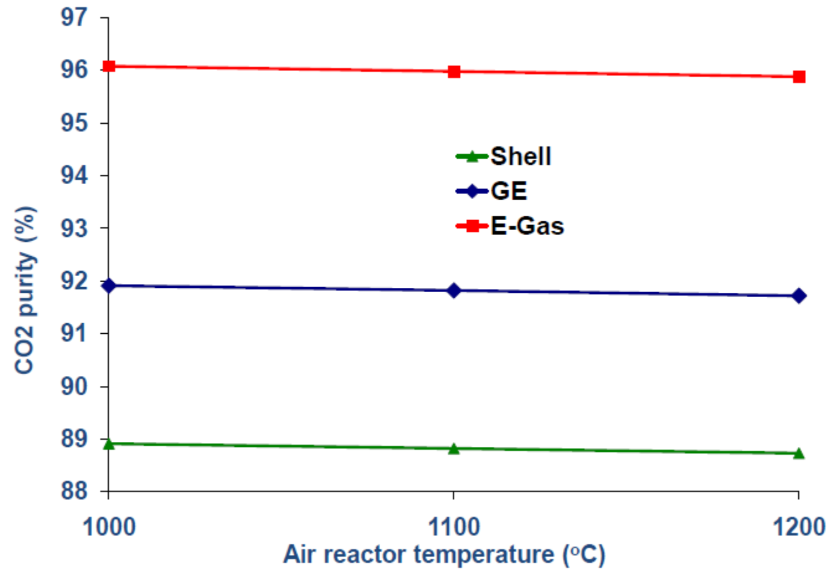
Component	GE (1,316 °C 5.6 MPa)	EGas (1,040 °C 4.2 MPa)	Shell (1,427 °C 4.2 MPa)
CO	38.9	45.4	61.5
H_2	38.4	32.4	31.2
CH_4	0.3	4.7	0.0
CO_2	17.8	15.1	0.1
H_2O	0.1	0.2	0.1
N_2	3.6	1.2	6.0
Ar	0.9	1.0	1.1
MW (kg/kmol)	21	22	20
HHV (kJ/kmol)	222,430	263,200	263,900

* From NETL Baseline Report on Power Plants (2007)

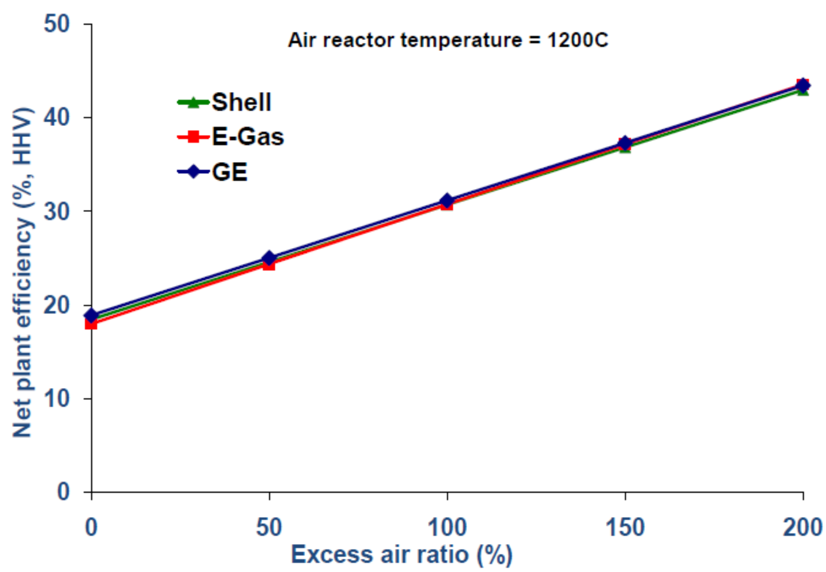
Fuel reactor temperature



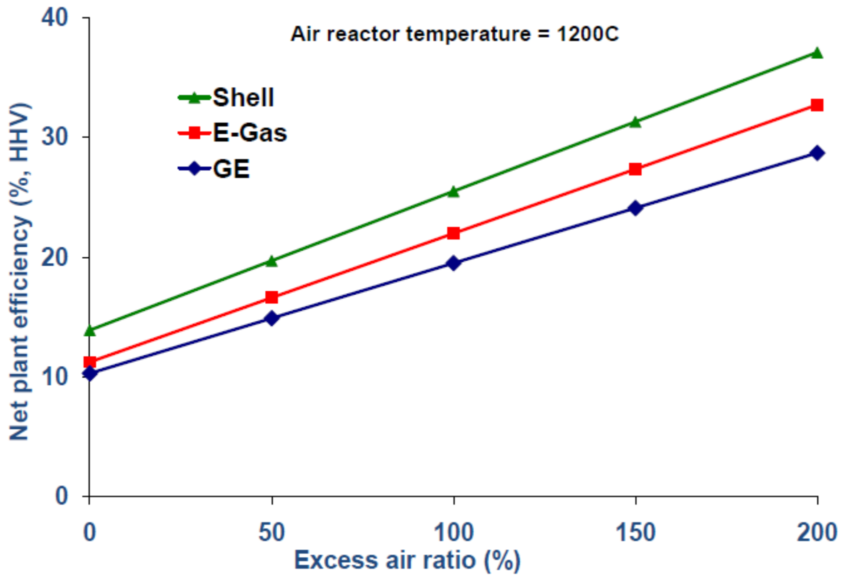
CO_2 purity



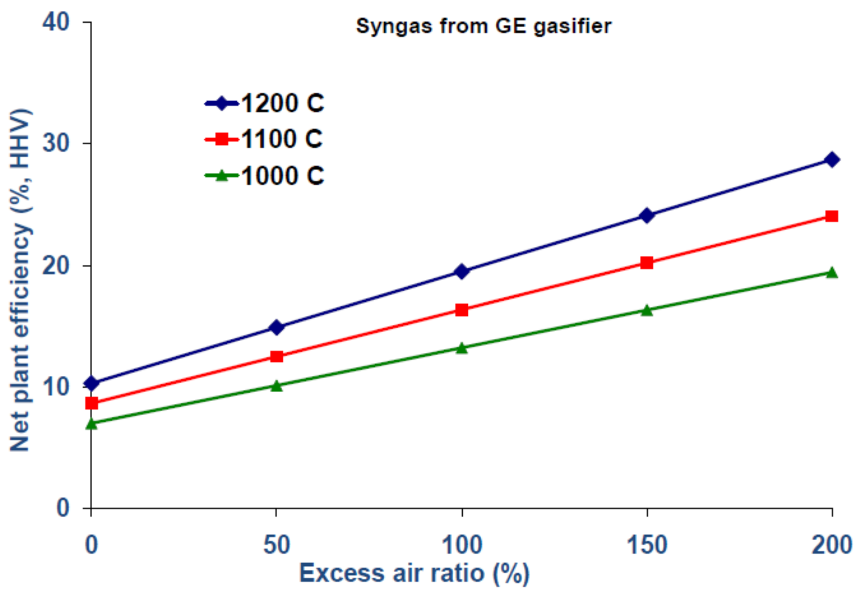
CLC efficiency for different fuels



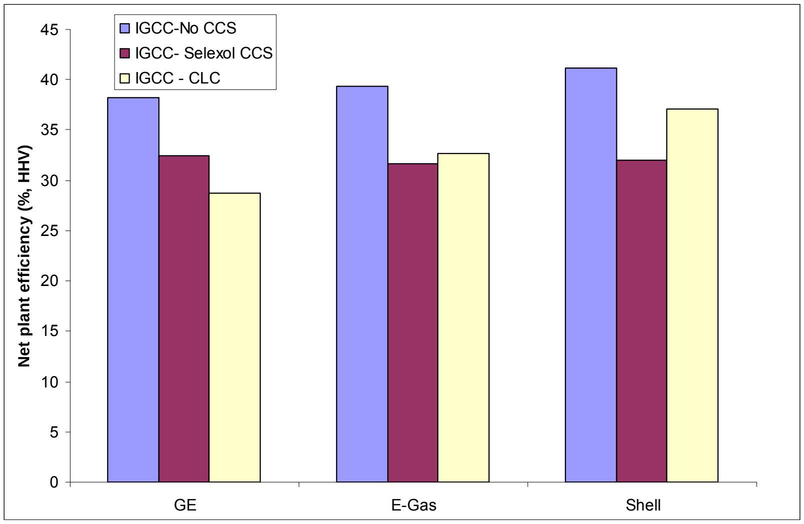
IGCC efficiency for different fuels



IGCC efficiency at different temperatures



Comparison with Selexol CCS



Conclusions

- CLC system efficiency doesn’t change with fuel
- IGCC system efficiency changes