E.ON’s Activities on IGCC and Zero Emissions Plant

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Rugeley - 20 June 2007
The Need for New Capacity

- By 2015 the UK will see up to 26GW of plant closures (LCPD and nuclear life expiry)

- With no new build, demand may exceed supply in winter peaks by about 2011

- Estimated 36 GW of new capacity needed by 2020 ~ 45% of UK capacity

Replacement with gas-fired CCGTs will not reduce overall CO2 emissions – and lead to ~70% gas dependency.
Replacement Generation Options

Considerations include:

• Government Policy (including post-Kyoto position, Security of Supply)
  – the Energy White Paper, EC Policy Initiatives, G8 ..........
• Environmental Performance
• Commercial Viability (including cost of fuel and carbon)
• Public Acceptability (a factor for new nuclear?)
• Technology maturity (clean coal technologies, marine?)
• Reliability (e.g. the intermittency of wind)
• Extent of Deployment (can enough be built in time; e.g small scale CHP, nuclear consenting)
CO₂ abatement from coal – twin track approach

Increased Efficiency, Biomass co-firing etc

Carbon Capture and Storage (CCS)

Baseline

- 23%

- 60%

- 95%

Possible Now

2010

2020

Medium Term

Long Term

Time

Source: IEA
CO2 Capture Options

1. Power plant
   Conventional

2. Gasification Reforming
   $H_2 + CO

3. Water-shift
   $H_2 + CO_2$

4. CO2 capture

5. Power plant
   Hydrogen-rich fuel

6. CO2 storage

- Exhaust, 0.3-0.5% CO2
- $2H_2 + O_2 \rightleftharpoons 2H_2O$
- Exhaust, 0.1-0.5% CO2
- $CH_4 + O_2 \rightarrow CO_2 + 2H_2O$
- Air separation
- Water removal

Coal
Oil
Natural gas

H2
GASIFICATION WITH CAPTURE
IGCC with CO₂ Capture

Current Position
• Killingholme
• Essence of the $1B US FutureGen project
• EU Hypogen/Dynamis project has similar goal
E.ON UK’s CCS project at Killingholme

Overview

- Killingholme will nominally be a 450MW IGCC+CCS fuelled on coal
- Built on or close to the existing Killingholme site
- Multiple CO₂ storage options identified in the Southern North Sea (SNS)

Killingholme could be operational by late 2011
The existing E.ON site is the front running site on which to build Killingholme IGCC.
Multiple CO₂ storage sites identified in the SNS

- Killingholme is well positioned for CO₂ evacuation from Easington and Theddlethorpe
- The vast majority of gas fields in the SNS are capable of storing CO₂
- The SNS is capable of storing 2.8BT of CO₂, Killingholme will produce 3MT of CO₂ pa.
Killingholme could be operational by 2011

Milestones

- Sept 2006 Feasibility study reports
- Jan 2007 – July 2007 Pre-FEED study
- Aug 2007 – May 2008 Full FEED study
- June 2008 Investment decision
- July 2008 – Sept 2011 Construction
- Dec 2011 Plant commissioning

This timetable is ambitious but is designed to ensure E.ON remains front-running utility on coal based carbon capture. Clearly there are factors that could cause delay.
OXYFUEL
Oxygen tank and evaporator
Carrier stream – ground floor
Civil works for bulk stream tower
Testing: results

Reduction in net flow
Operation: changeover
Emissions (CO₂, NO, SO₂, CO) and C burnout
Combustion stability
1. Warm up on gasoil, then switchover to coal for air baseline test
2. Revert to gasoil during switchover of carrier stream
3. Revert to coal for full switchover (bulk)
Changeover

Changeover and CO₂ concentration response time <10 minutes

<table>
<thead>
<tr>
<th>CO₂ [%vol,dry]</th>
<th>Gasoil, air = 14</th>
<th>Coal, air = 17</th>
<th>Coal, oxyfuel = 80</th>
</tr>
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Time elapsed [minutes]

Flows [kg/hr], CO₂ [%vol,dry]

Gasoil flow | Coal flow | CO₂
Changeover

Flow [kg/hr], CO2 [%vol,dry]

Time elapsed [minutes]

NO and SO2 [vpm,dry]

Gasoil flow
Coal flow
CO2
SO2
NO
Furnace exit gas temperature

- OXY - 1% O2, 0% OFA
- OXY - 1% O2, 15% OFA
- AIR - 1% O2, 0% OFA
- AIR - 1% O2, 15% OFA
Conclusions

~75% reduction in exhaust gas requiring treatment
~80% CO₂ content in dry exhaust gas
Reduction in NO concentration
Increase in CO, SO₂ concentration
Reduction in absolute levels of all emissions
Burnout degraded at low O₂ enrichment
Flame stability degraded
Reduced flame and gas temperatures
Increasing O₂ enrichment = closer to air
Achievements to date

>50 hours of operation in full oxyfuel mode
Improved stability during operation
Flame detection issues resolved
One man operation
Optimised controller response parameters
Recalibration of instruments
Fuel feed arrangements – difficult coal
>80% (dry) CO₂ concentration
Proof of trips and interlocks
O$_2$ enrichment – higher levels, enrichment of primary
Heat transfer
Fuel feeding and conveying
Flame detection
Tramp air ingress
Ash behaviour/fate of trace elements
Fouling behaviour
Corrosion
Implications for full scale

Oxyfuel combustion achievable
Staged combustion can reduce NO emissions, if required
Combustion efficiency similar to air can be achieved
Optimum O₂ enrichment likely to result in lower volume flow than air
SO₂ (and others?) concentrated by ~4 times
Attention needs to be paid to control and instrumentation
Scope for increased enrichment (>26%) without exceeding materials constraints, whilst reducing shaft work
Safety and efficiency improvements possible in milling