UK FEED Studies 2011 – A Summary

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IEA Greenhouse Gas R&D Programme
UKCCS/NCCS Biannual Meeting
Nottingham, UK
September 4th 2013
UK CCS Demonstration Feed Study

Two different Feed Studies:

- **Retrofit**: Scottish Power’s Longannet Power Station to Goldeneye Reservoir
- **New Build**: E.ON’s Kingsnorth Power Station to Hewett Gas Field

The Report: UK FEED Studies 2011 – A Summary

- Review of **206 documents** from E.ON and **123 documents** from Scottish Power FEED studies

Provide information on the basic design of large-scale CCS Demo Projects
# Report Outline

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### CCS Demo Project Overview

<table>
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<tr>
<th>Longannet</th>
<th>Kingsnorth</th>
</tr>
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<tbody>
<tr>
<td><strong>2400 MWe</strong></td>
<td><strong>1600 MWe</strong></td>
</tr>
<tr>
<td>4x 600 MWe Sub-critical coal-fired</td>
<td>2x 800 MWe, Supercritical coal-fired</td>
</tr>
<tr>
<td><strong>CO₂ Capture 2MT/y</strong></td>
<td><strong>CO₂ Capture 2.2MT/y</strong></td>
</tr>
<tr>
<td>20M tonnes by 11year</td>
<td>20M tonnes by 10-15 years</td>
</tr>
<tr>
<td><strong>Retrofit</strong></td>
<td><strong>New Build</strong></td>
</tr>
<tr>
<td>Amine based CO₂ Capture Unit</td>
<td>Amine based CO₂ Capture Unit</td>
</tr>
<tr>
<td><strong>Vapour (On Shore) / Dense (Off-Shore)</strong></td>
<td><strong>Vapour Phase</strong></td>
</tr>
<tr>
<td>Onshore: 260 km Existing &amp; 17km New; Offshore: 100 km Existing</td>
<td>Onshore: ~10 km New; Offshore: ~260 km New;</td>
</tr>
<tr>
<td><strong>Goldeneye gas field</strong></td>
<td><strong>Hewett gas field</strong></td>
</tr>
<tr>
<td>Existing Platform</td>
<td>New Platform</td>
</tr>
<tr>
<td><strong>Theoretical</strong>: 47 mtonne</td>
<td><strong>Modelled</strong>: 110 mtonne</td>
</tr>
<tr>
<td><strong>Expected</strong>: 30 mtonne</td>
<td><strong>Maximum</strong>: 206 mtonne</td>
</tr>
<tr>
<td>Estimated CAPEX 1200 to 1519 m£</td>
<td>Estimated CAPEX 942 to 1623 m£</td>
</tr>
</tbody>
</table>
## CCS Demo Project Consortium

### Longannet

- **Scottish Power**
  - CO₂ Capture Plant
  - Compression & Drying
- **National Grid**
  - St. Fergus Booster Compression
  - Onshore pipeline
- **Shell**
  - Goldeneye
  - Offshore pipeline

### Kingsnorth

- **E.ON, UK**
  - CO₂ Capture Plant
  - Compression & Drying
  - Onshore pipeline
- **ENT**
  - Hewett
  - Offshore pipeline
Power Plant: Longannet

Less Power Plant Integration

Foot print has increased due to CO₂ Capture Plant

Power and Steam Supply for CO₂ Capture Unit from existing plant is not the preferred solution for retrofit. Additional Auxiliary Boilers Installed to meet steam demand of capture plant

CCP output is clean so, Effluent Treatment plant is not required

Understanding of base load operation is required before flexibility demonstration
Power Plant: Kingsnorth

- Detailed Design to provide Operation Flexibility
- Flue Gas will be cooled and processed with Polishing FGD, WESP and Direct Contact Cooling
- Significant Part of Cooling Water Infrastructure will be re-used (i.e. from the infrastructure of the old power plant)
- Frequency response equipment should be fitted at Power Plant
- Potential to interface cooling and steam system between power plant and CO₂ capture plant
- FGD system should be fully functional before CO₂ Capture Unit Commissioning
## CO₂ Capture Unit

<table>
<thead>
<tr>
<th>Longannet</th>
<th>Kingsnorth</th>
</tr>
</thead>
<tbody>
<tr>
<td>90% CO₂ recovery</td>
<td>90% CO₂ recovery</td>
</tr>
<tr>
<td>Treat Flue gas from Unit 2 Or 3</td>
<td>Treat Flue gas of approx. 47.3% from total</td>
</tr>
<tr>
<td>Two CO₂ Capture Trains</td>
<td>Two CO₂ Capture Trains</td>
</tr>
<tr>
<td>Aker Clean Carbon Proprietary Solvent</td>
<td>Mitsubishi Heavy Industries KS1Solvent</td>
</tr>
<tr>
<td>60 meter High; Rectangular Absorber</td>
<td>72 meter High ; Rectangular Absorber</td>
</tr>
<tr>
<td>One stripper (each train)</td>
<td>Two strippers (each train)</td>
</tr>
<tr>
<td>Separate Heat and Power supply Unit for CO₂ Capture Unit</td>
<td>Steam is extracted from the IP and LP Crossover Pipe of the Power Plant</td>
</tr>
<tr>
<td>Tie in Utilities like Natural Gas, Flue gas, Cooling water, Potable water, Demi-water, Electricity</td>
<td>Tie in Utilities like Natural Gas, Flue gas, Cooling water, Potable water, Demi-water, Electricity</td>
</tr>
</tbody>
</table>
## CO₂ Compression & Dehydration

<table>
<thead>
<tr>
<th>Longannet</th>
<th>Kingsnorth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two 50% Compression and Drying Trains, Stages not confirmed</td>
<td>Two 50% Compression and Drying Trains, 4 stages each</td>
</tr>
<tr>
<td>Capacity: 1 Mtonne CO₂ per year</td>
<td>Capacity: 2.4 Mtonne CO₂ per year</td>
</tr>
<tr>
<td>Compression from 0.5 barg to 37 barg, Outlet Temp. 30°C</td>
<td>Compression from 1.5 bara to 39 bara, Outlet Temp. 40°C</td>
</tr>
<tr>
<td>Multibed Molecular Sieve Dryers</td>
<td>Multibed Molecular Sieve Dryers</td>
</tr>
<tr>
<td>&gt;90% CO₂; 50ppm H₂O; &lt;1ppmv O₂; &lt;1% N₂+H₂+CH₄+Ar</td>
<td>99%CO₂; 24ppmv H₂O; 0.02% O₂</td>
</tr>
<tr>
<td><strong>Dense Phase Compression at St. Fergus terminal</strong></td>
<td><strong>Dense Phase Compression at Kingsnorth</strong></td>
</tr>
<tr>
<td>Two 50% Five stage Integrally Geared Compressor Units</td>
<td>Two 50% Two stage Integrally Geared Compressor Units</td>
</tr>
<tr>
<td>Outlet pressure 80 to 120 barg, 15°C</td>
<td>Outlet pressure 87 bara, 40°C</td>
</tr>
<tr>
<td></td>
<td>Include the recovery of compression heat for condensate heating</td>
</tr>
</tbody>
</table>
CO₂ Transportation & Wells: Longannet

- Reusing existing pipeline reduces cost
- Better Understanding of CO₂ properties required for new pipeline development
- Impact of CO₂ properties on vents, block valves is important
- Low Water Content is required to minimize Corrosion
- Combination of injectors to cover variable flow rate
- Using existing offshore pipeline and wells have constraints
CO$_2$ Transportation & Wells: Kingsnorth

- Conversion of pipeline to dense phase after 20Mtonne CO$_2$ being injected
- Insulation required at the pipeline at topside upstream of well in winter
- Intermediate storage of CO$_2$ may not be required
- Two Phase flow in pipeline should be avoided
- High reliable Drying Process is installed to avoid Corrosion
- Insulation required at the pipeline at topside upstream of well in winter
## CO₂ Storage & Wells

<table>
<thead>
<tr>
<th>Longannet / Golden Eye</th>
<th>Kingsnorth / Hewett</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Depth:</strong> 2500m</td>
<td><strong>Depth:</strong> 1300m</td>
</tr>
<tr>
<td>Pressure when abandoned: ~138 bara</td>
<td>Current Pressure: 3 bara.</td>
</tr>
<tr>
<td>Original Pressure: ~265 bara</td>
<td>Original Pressure: 137 bara</td>
</tr>
<tr>
<td>Re-use of gas production platform in the Central North Sea</td>
<td>New-build platform in the Southern North Sea</td>
</tr>
<tr>
<td>Re-completion of 5 existing wells</td>
<td>3 initial new wells, 1 contingency, 5 additional for full phase = 9</td>
</tr>
<tr>
<td>Depleted gas field connected to aquifer</td>
<td>Very low pressure gas reservoir</td>
</tr>
<tr>
<td>13 abandoned E&amp;A wells outside immediate area of store</td>
<td>Multiple existing wells in store</td>
</tr>
<tr>
<td>Continuity from gas producer to CO₂ storage</td>
<td>Working entirely with 3rd party data</td>
</tr>
</tbody>
</table>
**CO₂ Storage: Longannet, Goldeneye**

Well characterised field. Properties well understood after 7 years of production.

Small potential of hydrate formation; which can be controlled.

Hydraulic connectivity with underlying aquifer.

Highly Unlikely that CO₂ will migrate to the surface in significant amount.

Risk based monitoring programme and corrective measures plan.
CO$_2$ Storage: Kingsnorth, Hewett

Primary storage formation is l. Bunter sandstone. Secondary storage in u. Bunter.

Risk assessment has not been finished though the initial HAZID was completed.

Even with limited data, modelling work complete.

Some data is not available like full logs suits for all wells, improved seismic data, monthly production data.
Identifying & Managing Risk...

- Residual Technical Risk
  - Power Plant and CO₂ Capture Facilities
  - Pipeline Design Operation
  - Platform
- Health and Safety Issues
- Project Risk
  - Project Cost
  - Project Performance
  - Technical Cost
Residual Risks after FEED

- Condensation and re-vapourisation of liquid during linepack – Operational Flexibility
- Wellbore stability (liquid formation)
- Need to maintain as single phase
- OLGA heater model stability
- Extent of CO₂ slippage behind
- Heat of mixing effects air / CO₂
- Operation of pipeline with superheat (<= 30°C during dense phase)
- OLGA JIP project - to validate a module – flow experiments

Follow on Challenges...

Final CO₂ specification to be confirmed

Finalise steam and power supply

Conclude work on modularisation v. stick build

Power station and capture plant flexibility

Review the Operability, Reliability, Availability and Maintainability (RAM) of the whole chain

CO₂ Conditioning

Following the Capture process, CO₂ is pressurised, deoxygenated and dried to meet the pipeline specification...

<table>
<thead>
<tr>
<th>Composition Mole Fraction</th>
<th>Coolant Pressure Leaving Longannet barg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide – CO₂</td>
<td>&gt;99%</td>
</tr>
<tr>
<td>Water – H₂O</td>
<td>50ppm</td>
</tr>
<tr>
<td>Oxygen – O₂</td>
<td>1ppm</td>
</tr>
<tr>
<td>N₂ + H₂ + CH₄ + Ar</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Pressure Leaving Longannet</td>
<td>34 barg</td>
</tr>
</tbody>
</table>
Risks Assessment Exercise: Longannet

- Explosion in Power Plant & CHP Unit
- Failure of process plant, CO₂ release
- Loss of containment, Solvent Handling, Natural Gas Release
- Asphyxiation of CO₂ present at base of cooling tower
- Compression and Drying Overpressure, Contamination

- Water Content, Volatile component, Accumulation of Particulate
- Leakage, Loss of Utilities, Overpressure of Onshore Pipeline
- Backflow from Onshore pipeline

- CO₂ release e.g. from subsea, accidental, venting
- Cryogenic effects during pressure reduction of vapour and dense phase
**Recommended Safeguards: Longannet**

- Measurement of key process parameters and installed appropriate control measurements
- Need to consider cold weather, Solvent tank filling / offloading
- Place entry precaution & installing CO₂ and O₂ detectors
- Risk assessment for compressor failure

- Specify water content, CO₂ composition limit
- Correct material selection and maintenance
- Specify a High Integrity Pressure protection

- Minimize HP and LP interface
- Apply simple but reliable process control to avoid over engineering
- No CO₂ storage onshore and offshore
Risks Assessment: Kingsnorth

- Plant Failure, Fracture of steam pipe / reclaimer
- CO₂ release, Flue gas leak
- Loss of containment, Solvent leak, Amine emission
- Vacuum on steam and condensate line
- Compression and Drying CO₂ leak, Contamination

- Uncontrolled CO₂ loss, due to overpressure of compression, overstressing pipeline due to high temp.
- Pipeline Corrosion, Flange leak, Mechanical Failure
- Offshore installation fires / collapse

- CO₂ release to sea/ atmosphere, potential migration to other formation
- Well material degradation
Recommended Safeguards: Kingsnorth

- Building, Site Drain and Isolation procedures
- Closed circuit cooling, Monitoring, Review of maintenance inspection regime
- Integrity management and control system
- Reflected vacuum conditions in system design
- CO₂ detection & warning system, use of isolation valves

- Compression design to ensure pressure does not exceed MAOP of pipeline, SIL rated temperature trip
- Pipeline Coating, Minimization of Flange and take-off line
- Pipeline Integrity Management System

- Wellhead design for integrity, CCS plant dehydration integrity
- Robust Monitoring Programme
- Compatibility between elastomers and CO₂ is recognised
Regulatory

Scottish Power CCS Consortium – Key Consenting Requirements
Scottish Power CCS Consortium

Key Consents Issues included:

- Section 36 Objections – stakeholder engagement programme
- HSE uncertainty on CO₂ in COMAH – could result in additional requirements later
- Carbon Storage Licence cannot be issued until DECC completed SEA
- Uncertainty over handover storage regulations
- Lease schedule from Crown Estate
E.ON CCS Consortium

Key Consents Issues included:

- Significant uncertainties at outset of project
- Resolved for power plant, capture, onshore and offshore pipelines
- Uncertainty remained for offshore platform and storage – platform location not known at FEED stage, regulations interpreted and would need review on actual application for consents
INTERFACE MANAGEMENT

Gelsenkirchen
Nottingham

Aberdeen
London
Essen

Nottingham
Reading
Tokyo

Aberdeen
Norwich
Cheshire
Power Plant and Retrofit CO₂ Capture Lessons Learned

FEED design assumptions
Key challenges investigated during FEED
Capture plant scale up risks
Key insights
CO₂ conditioning
Follow on challenges

The ScottishPower Consortium were designing a retrofit CO₂ capture solution
Other Key Lessons Learned

Experienced involving regulatory impact to the project.

• Important to note that these experiences are in context of UK having a relatively advanced regulatory environment, but still not complete, and projects are first in this regulatory environment

Complexity needs to be managed

Joint and early engagement with regulators, key stakeholders, communities

Good working relationship with regulators is vital

Consent risks to be included in project risk management

Challenging to proceed with uncertainties over injection platform location
Acknowledgement

IEAGHG Capture & Integration Systems
  • Dr. Jasmin Kemper
  • Dr. Prachi Singh
  • Dr. Stanley Santos

IEAGHG Geological Storage
  • Ms Ludmilla Basava-Reddi

IEAGHG Geological Storage and Regulatory Support
  • Ms Samantha Neades
  • Mr Tim Dixon

COFree Technology Ltd / IEAGHG
  • Mr Michael Haines