Aspects of CCS for Kingsnorth and Maasvlakte (ROAD)

Robin Irons

APGTF
13th March 2012
ROAD means...

<table>
<thead>
<tr>
<th>ROAD</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Rotterdam</td>
<td>Capture</td>
</tr>
<tr>
<td>Opslag</td>
<td>Storage</td>
</tr>
<tr>
<td>Afvang</td>
<td></td>
</tr>
<tr>
<td>emonstratieproject</td>
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</table>
Co-operating Partners ROAD

Maasvlakte CCS Project C.V. is a joint venture of:

- E.ON Benelux
- GDF SUEZ Energie Nederland (GDF SUEZ Group)

In co-operation with intended partners:

- TAQA Energy
- GDF SUEZ E&P

With financial support of:

- European Commission (EU)
- Government of the Netherlands
- Global CCS Institute
Kingsnorth CCS

- Existing 2000MW station units 1-4 to close by 2013
- Two new units proposed, each 800MW giving 1600MW total
- 3-400 MW of CCS from Day 1
- Capable of burning UK coal and a proportion of biomass, and delivering local heat

The new station would have
- Cut specific carbon emissions by 35% compared to existing coal
- Provided reliable power for London
- Been ready for full CCS
- Kick started a Thames CCS Cluster
- Met all modern environmental standards (dust, sulphur, NOx...)
Kingsnorth CCS - Capture – CO2 specification

- CO2 extraction from flue gas;
- Produces water-saturated CO2;
- CO2 dried to ~24ppm for corrosion management;

<table>
<thead>
<tr>
<th>CO2 Composition</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2</td>
<td>&gt;99.7%</td>
</tr>
<tr>
<td>Temp</td>
<td>40 °C</td>
</tr>
<tr>
<td>H2S</td>
<td>Nil</td>
</tr>
<tr>
<td>CO</td>
<td>Nil</td>
</tr>
<tr>
<td>Hydrocarbon</td>
<td>&lt;10 ppmv</td>
</tr>
<tr>
<td>O2</td>
<td>&lt;15 ppmv</td>
</tr>
<tr>
<td>N2</td>
<td>&lt;130ppmv</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CO2 Volumes</th>
<th>Generation</th>
<th>Tonnes per hour</th>
<th>Tonnes per day</th>
<th>Tonnes per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>300MWe = 400MWg</td>
<td>~275</td>
<td>~6600</td>
<td>~2.2 M</td>
</tr>
<tr>
<td></td>
<td>Competition volume</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1600MWg 100% Kingsnorth</td>
<td>~1100</td>
<td>~26400</td>
<td>~9 M</td>
</tr>
<tr>
<td></td>
<td>Including 3rd parties</td>
<td>2500</td>
<td>60,000</td>
<td>20 M</td>
</tr>
</tbody>
</table>

Strategic Opportunity: “Thames Cluster”
Kingsnorth CCS: Offshore pipe

- 275 km Kingsnorth to Hewett
  - Includes 8km onshore
- 36 inch (910mm) mild steel pipe
  - concrete coated
Kingsnorth CCS: Offshore – platform(s)

- Normally Unmanned Installation (NUI) with limited facilities
- New build with a 40 year design life
- Controlled from Kingsnorth – Fibre Optic
- Future requirement for second platform for heating \( \text{CO}_2 \) when dense phase

Typical “Not Normally Manned” platforms

Capture → Compress → Transport → Offshore → Store
Kingsnorth CCS: Offshore Storage: Hewett Reservoir and Area

- Lower Bunter sandstone
- Depth: 1300m
- Current pressure: 3 bara.
- Original pressure: 137 bara.
- BH Temp: 52C
- Good Porosity
- Good Permeability
- CO2 Capacity ~210m Te.
Location: Maasvlakte Power Plant 3
Capture

- Post combustion capture
- 250 MW equivalent
- 90% capture efficiency
- CO$_2$ captured: 1.1 Mt/year
- Operational 2015
ROAD CO\textsubscript{2} Transport

- **Pipeline length:**
  - 5km onshore, 20km offshore
- **Diameter:** 16”
- **Capacity:**
  - 1.5 mln tonne / year (gaseous)
  - 5 mln tonne / year (dense)
- **Design specs:** 175 bar, 80 °C
- **Pipeline insulated**
ROAD CO₂ Storage Location

- Depleted gas reservoir P18
- Operator: TAQA
- Depth: 3,500 m
- Capacity: 35 mln tonne
- Available: 2014
- Original pressure: 350 bar
- Expected pressure at start of CO₂ injection: < 30 bar
Commercial Challenges of CCS

The main commercial challenges of CCS are:

• Cost of CCS: Capex and Opex;
• Financing of CCS projects;
• Asset utilisation: operating regime of CCS plant;
• Cost comparison of alternative technologies;
Commercial Challenges of CCS: Costs

- CCS isn’t a “First of a Kind” technology yet – it is a pre “First of a Kind” technology:
  - Capex costs are obtained from FEED/bids;
  - Opex costs are potentially more difficult:
    - Main cost is “lost efficiency” from turbine steam ~10%;
    - Costs reduced by EU ETS credit but EU ETS price signals unclear.

Source: DECC CCS Industry Day – 15th December 2011

Source: Blloomberg – 3 year EU ETS prices
### Commercial Challenges of CCS: Costs (cont)

- Table shows published CAPEX for Longannet & Kingsnorth & estimate for Peterhead Gas CCS: Is £1bn capex achievable?

<table>
<thead>
<tr>
<th>Capex Cost Estimate Comparison</th>
<th>Longannet £m</th>
<th>Peterhead £m</th>
<th>Kingsnorth £m</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCR etc</td>
<td>262</td>
<td>??</td>
<td>0</td>
<td>Unclear allocation of costs at L'gannet: assume for SCR/SD/SOx at P/Head unclear</td>
</tr>
<tr>
<td>Capture</td>
<td>348</td>
<td>348</td>
<td>214</td>
<td>Capture Plant sizes different: KCSS efficiency higher than L'gannet. Probably some allocation differences between capture &amp; compression (i.e. dehydration plant)</td>
</tr>
<tr>
<td>Compression</td>
<td>47</td>
<td>47</td>
<td>97</td>
<td>Allocation differences? See above</td>
</tr>
<tr>
<td>Onshore Pipeline (new)</td>
<td>81</td>
<td>81</td>
<td>20</td>
<td>Very short length at KCSS</td>
</tr>
<tr>
<td>Onshore Pipeline (reuse)</td>
<td>79</td>
<td>-</td>
<td>-</td>
<td>National Grid existing pipeline</td>
</tr>
<tr>
<td>Gas Terminal Compression &amp; Liquifaction</td>
<td>121</td>
<td>121</td>
<td>0</td>
<td>L'gannet &amp; P/Head have dense phase transport = another cost stage not required for KCSS</td>
</tr>
<tr>
<td>Offshore pipeline (new)</td>
<td>-</td>
<td>-</td>
<td>578</td>
<td></td>
</tr>
<tr>
<td>Offshore wells and storage (new)</td>
<td>-</td>
<td>-</td>
<td>227</td>
<td></td>
</tr>
<tr>
<td>Offshore pipeline, wells and storage (reuse)</td>
<td>208</td>
<td>208</td>
<td>-</td>
<td>Very cheap solution - but large contingency needed</td>
</tr>
<tr>
<td><strong>Subtotal Capex (£m)</strong></td>
<td>1,146</td>
<td>805</td>
<td>1,136</td>
<td></td>
</tr>
<tr>
<td>Contingency</td>
<td>372</td>
<td>195</td>
<td>See below</td>
<td></td>
</tr>
<tr>
<td><strong>Total Capex (£m)</strong></td>
<td><strong>1,518</strong></td>
<td><strong>1,000</strong></td>
<td><strong>1,136</strong></td>
<td></td>
</tr>
<tr>
<td>Contingency %</td>
<td>32%</td>
<td>24%</td>
<td>15% (included above)</td>
<td></td>
</tr>
</tbody>
</table>
Overall Kingsnorth FEED summary is available in the Key Knowledge Reference Book on DECC website:
Kingsnorth Capture Plant Design Basis

- 819MWe boiler – supercritical steam
- 47.3% of flue gas (~ 390MWe net)
- 90% CO₂ capture rate
  - Capture plant ~ 300-320 MW net elec. output
- 25 year design life
- Availability >90%
- 4 year outage cycle
- Ramp rates
  - 4-6% MCR/min between 50-90% boiler load
  - 2-3% MCR/min from 30-50% and 90-100% boiler load

- Capture plant must not limit power plant operating range, including availability and flexibility.
- Maximise capture plant operation over power plant load range
Heat and Material Balance

• 100% boiler load case:
  • 1,143,118 Nm³/h flue gas feed
  • 920,033 Nm³/h treated gas
  • 2 x 72,582 Nm³/h CO₂ product to compression
  • 2 x 1,266,748 kg/h lean amine circulation

• 60% boiler load case – 871,961 Nm³/h flue gas feed
• 25% boiler load case – 469,699 Nm³/h flue gas feed

• Compositions and conditions available for all streams excluding KS-1 solvent streams (MHI proprietary)
Overall Layout - Split
Overall Layout

• Selection approach
  • Layout workshop – no clear differentiation
  • HAZID workshop – “
  • CAPEX assessment – “
  • OPEX assessment – “

• No clear winner!
  • Split option selected as base
  • Investigate in detailed design
**ROAD Timepath and Milestones**

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 July 2009</td>
<td>EU project proposal submission</td>
</tr>
<tr>
<td>September 2009</td>
<td>Project selection by EU</td>
</tr>
<tr>
<td>May 2010</td>
<td>Dutch government support</td>
</tr>
<tr>
<td>September 2010</td>
<td>EIA (MER)-publication memorandum</td>
</tr>
<tr>
<td>Q2 2011</td>
<td>EIA (MER) and permit application</td>
</tr>
<tr>
<td>Q1 2012</td>
<td>Final Investment Decision</td>
</tr>
<tr>
<td>2013</td>
<td>Commercial operation E.ON MPP3</td>
</tr>
<tr>
<td>2015</td>
<td>Full CCS-chain operational</td>
</tr>
<tr>
<td>2015 - 2020</td>
<td>Demonstration phase CCS chain</td>
</tr>
</tbody>
</table>
ROAD Permits

- **Capture permits:**
  - Environmental
  - Water
  - Building
  - Nature Protection

- **Transport & Storage permits:**
  - Updated zoning plan
  - Water
  - Environment
  - Endangered Species
  - Storage

Consultation complete on draft, “definitive” permit awaited

Consultation complete on draft, “definitive” permit awaited

Nearly there (we hope!)
Rotterdam Climate Initiative (RCI)

The Rotterdam Climate Initiative is a partnership between the City of Rotterdam, the Port of Rotterdam, DCMR Environmental Protection Agency Rijnmond, and Deltalinqs, with the objective of reducing CO₂ emissions by 50% and climate proofing the city.

Mission & ambition

- Improving the climate for the benefit of people, the environment, and the economy; that is the challenge confronted by the collective initiators; Port of Rotterdam, the City of Rotterdam, employers' organization Deltalinqs, and DCMR Environmental Protection Agency Rijnmond.

- The Rotterdam Climate Initiative creates a movement in which government, organizations, companies, knowledge institutes, and citizens collaborate to achieve a fifty per cent reduction of CO₂ emissions, adapt to climate change, and promote the economy in the Rotterdam region.
Rotterdam CCS Network 2011

1. Shell Permis
2. E.ON-ROCA
3. E.ON CO₂-Catcher (CATO-2 pilot project)
4. Abengoa

- Maasvlakte II, under construction
- CO₂ capture
- Green houses
- Transport by pipeline
- Energy intensive industry
- Transport by ship
- CO₂ Hub
- Greenhouses in region South Holland
- Greenhouses in area Linsengerland
Rotterdam CCS Network 2025

1. Shell Pernis
2. E.ON-ROCA
3. ROAD
4. Abengoa
5. Air Liquide
6. CO₂ Hub CINTRA
7. Air Products

Maasvlakte II, under construction (not just large scale demo’s)
CO₂ capture
Green houses
Energy intensive industry
CO₂ Hub

Connecting industry to CCS network
Transport by pipeline
Transport by ship

Pegasus: location not yet determined
IN 2025:

- **CO₂ transport by pipeline**
  - Rotterdam
  - Antwerp
  - Moerdijk
  - Geleen
  - Ruhrgebiet
- **CO₂ transport by sea vessel**
  - Norway, UK
- **OCAP: CO₂ to greenhouses**
- **CO₂ storage opportunities in Dutch gasfields**
- **CO₂ capture opportunities**
- **Vision Rotterdam CO₂ hub**

**Notes:**

- Transportation of CO₂ to greenhouses in Rotterdam and Moerdijk, with opportunities in Dutch gasfields for CO₂ capture and storage.
Rotterdam Climate Initiative (RCI)

RCI has presented a vision on why:

- CCS in Rotterdam is good for the climate
- CCS in Rotterdam will protect jobs
- CCS in Rotterdam will protect the future economy

- Win for the local population
- Strong political backing
ROAD Commercial Structure

- Grants are all fixed
  - € 180 M from EU - % of Capex
  - € 150 M from NL – 50% linked to Capex
  - ~50% linked to operation

- Demonstration ends 2019 – plant free for commercial operation from 2020

- c/f NER 300 and UK Govt
  - obligations for longer term running

Results:

- Can accept reliability risk (more innovation & cheaper)
- Focus on minimum cost
Lessons

Final Thoughts

- Kingsnorth and ROAD have similarities and cross-fertilisation of ideas but different cost-base due to local circumstances

- Solution must work in a Commercial world – both Cost and Funding Structure are important to maximise likelihood of success.

- Political support & public acceptance is crucial
  - RCI or similar regional support invaluable
  - Off-shore storage eases consenting

- Competitive procurement and commercial considerations can conflict with planning process