Joint CO$_2$GeoNet - EERA Research Workshop
Venice, 13 May 2015

Rotterdam Opslag en Opvang Demonstratieproject (ROAD)
*Project Update and Lessons Learnt*

Onno Tillema, Project Director ROAD
Agenda

• Introduction to ROAD

• Lessons Learnt:
  o Permitting Process
  o Capture Integration
  o Project Management and Funding

• ROAD: Stepping Stone for CO₂ Hub in Rotterdam and Europe
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Co-operating Partners ROAD

- **Maasvlakte CCS Project C.V.** is a joint venture of:
  - E.ON Benelux
  - GDF SUEZ Energie Nederland
- 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
  - Private partners (discussions pending)
Integrated CCS Chain ROAD

Maasvlakte Power Plant 3

Capture Plant

Compression

Onshore Pipeline: 5km

Offshore Pipeline: 20km

P18-A Platform

Depleted Gas Reservoir P18-4

-3,500m

-25m

NOT ON SCALE
Capture Location: Maasvlakte Power Plant 3

- Output: 1,070 MWe
- Efficiency: 46%
- Operational: 2015 (currently in hot commissioning)
- Capture ready
CO₂ Capture Unit

- Post combustion (Fluor)
- Size: 250 MW equivalent
- Capture rate: 90%
- CO₂ capture:
  - 169 t/h
  - 1.1 Mt/yr
- Operational: 2018
CO₂ Transport

- Pipeline length:
  - 5 km onshore
  - 20 km offshore
- Diameter: 16 inch
- Transport capacity:
  - 5 Mt/yr (dense)
- Design specs:
  - 140 bar (max.)
  - 80 °C (max.)
- Pipeline insulated
CO$_2$ Storage Location

- Depleted gas reservoir P18
- Operator: TAQA
- Depth: -3,500 m
- Storage capacity:
  - 35 Mt (P18)
  - 8 Mt (P18-4)
- Available: 2017
- Alternatives / future expansion options are in focus (i.a. EOR)
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Complexity and Dynamics of Permitting Process

- Dutch government structure comprising four layers of governments:
  - Local: municipalities
  - Regional: water authorities
  - Provincial: provinces
  - National: ministries and national advisors

- New environmental acts came into force during permitting process:
  - Decision on State Coordination Scheme Energy Infrastructure Projects (March 2009)
  - Act on Modernising Environmental Impact Assessment (July 2010)
  - Amendment of Mining Act as implementation of EU CCS Directive 2009/31/EC (September 2011)
  - Act on General Conditions in Environmental Law (October 2010)
  - Decision on Environmental Impact Assessment (April 2011)

*Dutch ministry of Economic Affairs was essential in coordinating permitting stakeholders*
Permitting Framework ROAD: General

<table>
<thead>
<tr>
<th>Legislative requirement</th>
<th>Law</th>
<th>Competent Authority</th>
<th>Applicant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Impact Assessment (EIA)</td>
<td>Environmental Protection Act</td>
<td>Ministry of Economic Affairs, Agriculture and the Ministry of Infrastructure and Environment; Province of South-Holland (delegated to DCMR Environmental Protection Agency Rijnmond)</td>
<td>Proponent (ROAD)</td>
</tr>
<tr>
<td>Emission permits (for capture, transport and storage)</td>
<td>Environmental Protection Act</td>
<td>Dutch Emission Authority</td>
<td>Proponent</td>
</tr>
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</table>
## Permitting Framework ROAD: Capture

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<td>All-in-one permit for physical aspects</td>
<td></td>
<td>Province of South-Holland (delegated to DCMR Environmental Protection Agency Rijnmond)</td>
<td>Proponent</td>
</tr>
<tr>
<td>Environmental Permission</td>
<td>General Environmental Conditions Act</td>
<td>Province of South-Holland</td>
<td>Proponent</td>
</tr>
<tr>
<td>Building Permission</td>
<td>Nature Protection Act 1998</td>
<td>Province of South-Holland</td>
<td>Proponent</td>
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<tr>
<td>Natural Protection Act Permit</td>
<td>Water Act</td>
<td>Ministry of Infrastructure and Environment (delegated to the State Water Authority, Department South-Holland)</td>
<td>Proponent</td>
</tr>
<tr>
<td>Water Permit</td>
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## Permitting Framework ROAD: Transport

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<tr>
<td>State Zoning Plan</td>
<td>Spatial Planning Act</td>
<td>Ministry of Economic Affairs, Agriculture and Innovation and the Ministry of Infrastructure and Environment</td>
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<td>Environmental Impact Assessment</td>
<td>Environmental Protection Act</td>
<td>Ministry of Economic Affairs, Agriculture and Innovation and the Ministry of Infrastructure and Environment</td>
<td>Ministry of Economic Affairs, Agriculture and Innovation and the Ministry of Infrastructure and Environment / Proponent</td>
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<tr>
<td>Water Permit</td>
<td>Water Act</td>
<td>Ministry of Infrastructure and Environment (delegated to the State Water Authority, Department South-Holland)</td>
<td>Proponent</td>
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<tr>
<td>Railway Permit</td>
<td>Railway Act</td>
<td>ProRail</td>
<td>Proponent</td>
</tr>
<tr>
<td>Flora and Fauna Act Exemption</td>
<td>Flora and Fauna Act</td>
<td>Ministry of Economic Affairs, Agriculture and Innovation</td>
<td>Proponent</td>
</tr>
</tbody>
</table>
## Permitting Framework ROAD: Storage

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<tr>
<td>All-in-one permit for physical aspects</td>
<td>General Environmental Conditions Act</td>
<td>Ministry of Economic Affairs, Agriculture and Innovation</td>
<td>TAQA</td>
</tr>
<tr>
<td>Storage Permit</td>
<td>Mining Act</td>
<td>Ministry of Economic Affairs, Agriculture and Innovation</td>
<td>TAQA</td>
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ROAD submitted final version of EIA Notification in September 2010
Permitting Process Timeline

- September 2010: Starting note Environmental Impact Assessment published
- June 2011: Submitting Environmental Impact Assessment and publication of all permit applications
- May 2012: Capture permits definitive and irrevocable
- September 2013: Storage permits definitive and irrevocable
- May 2015: Transport permits agreed, with publication ready
Lesson Learnt on Permitting Process ROAD

1. Alignment of permitting authorities: Dutch ministry of Economic Affairs was essential in coordinating permitting stakeholders and showing national relevance of project via State Coordination Scheme

2. Education and building trust of stakeholders: permitting authorities not only want to be informed on procedures, but also want to be educated on technical details of the project, as early as possible

3. Commitment of permitting authorities: contact persons at permitting authorities have to be well-connected and committed to project. Lack of sufficient resources (e.g. time, knowledge) can severely delay project
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Location of Capture Plant: Maasvlakte Power Plant 3
Interactions Between Power Plant and Capture Plant

[Diagram showing interactions and flow of materials between the power plant and capture plant, including electricity, flue gas, CO₂, and water streams.]
Key Interfaces

- Flue gas
- Steam and condensate
- Electrical power
- Cooling water
Flexibility of Capture Plant and Control Philosophy

• In highly competitive power market controlled shut-down and return to service of capture plant on hourly basis is necessary

Operation modes of capture plant:
• Start-up capture plant with MPP3 already in operation at any load*
• Ramping up and down capture plant and MPP3 in parallel at the same ramp rate*
• Ramping up and down capture plant and MPP3 in parallel at different ramp rates
• Ramping up and down the capture plant leaving MPP3 in stable operation at any load
• Stable operation capture plant with MPP3 ramping up and down*

* Expected to be used mostly. Capture plant shall be optimized for these modes, without restricting operation in other modes mentioned
Lessons Learnt on Capture Integration

1. Way ROAD project is funded, with substantial capital grants, but a low reward for operation, created a strong incentive to minimise capital costs, with a much lower focus on reliability.

2. Focus on minimizing capital costs had a high impact on some major design choices. Capture plant is single train (including a single compressor). For interfaces with MPP3, capacity margins in MPP3 design are used for capture plant where possible.

3. Because of relatively small capture plant size, capture plant could make use of MPP3’s electric auxiliary system, MPP3’s cooling water system, extraction of steam from existing steam cycle of MPP3.

4. Engineering capture plant together with power plant would have led to other solutions with lower CAPEX, e.g. more optimal lay-out and combining utility system.
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Project Schedules and Impact of Delays

- Phase 1 (2009 and 2010): target FID by end 2010

- Phase 2 (2011 and Q1 2012): target to finish construction by end 2014 (FID by implication end 2011 or early 2012), again driven by an EC grant timetable (subsequently relaxed)

- Phase 3 (Q2 2012 onwards): “slow mode”. Since Q2 2012, the project has focused on only work that would avoid significant cost escalation, or improve funding
Funding and Commercial Issues

• CAPEX cost estimate has risen because of:
  o Inflation, as construction is delayed at least 3 years
  o Some design modifications add cost (principally provision for a wet ESP for emissions control and a tie-in for future CO₂ network in Rotterdam)
  o Cost of demobilization and remobilization
  o Cost of maintaining project team during “slow mode”
• OPEX cost estimate has reduced because:
  o Forecast electricity prices are lower. ROAD uses about 1 MWh of electricity for every 3 tonnes of carbon captured, making electricity costs of order half total OPEX
  o Minimum amount of CO₂ stored has been reduced to 4 Mt, with possibilities under discussion to lower it further. Intent is that a later separate funding scheme will pay for longer term operation. It is not intent to build plant and then decommission it after 4 years operation
• Forecast carbon prices have reduced substantially
Status ROAD

- **Engineering**
  - Detail engineering of capture plant underway, FEED is complete
  - Some long lead suppliers chosen and components engineered
  - Pipeline route engineered and ‘flow assurance’ study completed
  - ‘Tie-ins’ (i.a. flue gas, steam) with power plant installed
  - Storage design complete, detail storage FEED ready to start

- **Permits**
  - Permitting procedures finalized (beginning 2012)
  - Capture permits are definitive and irrevocable
  - Storage permits are definitive and irrevocable (TAQA) - Sept 2013
  - Transport permits agreed, with publication ready

- **Contracts**
  - Capture supplier selected and EPC contract was ready to be signed (on hold)
  - Contracts with power plant (utilities etc) ready for signature
  - Commercial contracts for transport (GDF Suez) and storage (TAQA) are agreed textually, and will be signed at FID
  - But, price validity has expired - reconfirmation once funding gap is closed

- **Finance**
  - Very low CO₂ prices have caused a financing gap compared to plan (>100M)
  - Delay in CCS role-out and loss of confidence in EU low carbon energy policy has also weakened the strategic case for the demo
  - Currently, phased approach is being investigated by EC and several Member States in order to finance construction and initial operation

ROAD remains ready to start construction as soon as the funding gap has been closed
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Rotterdam Vision: CO₂ Hub of Northwest Europe
Rotterdam CO\textsubscript{2} Hub - Existing OCAP* System

OCAP System:

- Supplies 400 kt CO\textsubscript{2} to \approx 600 greenhouses
- Shell Pernis CO\textsubscript{2} is from natural gas-based hydrogen production facility
- Abengoa is a first generation bio-ethanol plant
- OCAP claims CO\textsubscript{2} emission reduction of \approx 200 kt/year through avoidance of natural gas use in the greenhouses
- There is additional CO\textsubscript{2} demand OCAP can’t meet

\* OCAP: Organic CO\textsubscript{2} for Assimilation by Plants
ROAD as Stepping Stone for CCS in Europe

ROAD is one of best positioned CCS demonstration project in EU ready to be implemented:

- Efficient, new generation power plant (capture ready)
- Port and industrial area of Rotterdam (local support)
- Proximity of source to sink (25 km)
- Offshore storage (available storage capacity)
- National regulation and required permits completed
- Start of integrated CO\textsubscript{2} network in Rotterdam and NW Europe
Rotterdam CO₂ Hub: First Steps
The Proposed Link between ROAD and OCAP

- OCAP cannot expand due to lack of CO$_2$ in summer peak (usually a few days only)
- ROAD could supply OCAP with summer peak CO$_2$
- Expansion is desirable to reduce CO$_2$ emissions by greenhouses
  - Estimate of greater than 200kt/yr further reduction achievable (with heat pipe - to be confirmed)
- In winter CO$_2$ from Shell and Abengoa (bio-CCS) could be sent for geological storage by ROAD
Rotterdam CO₂ Hub: Vision 2030

- Power plants
- Industrial gases
- Refineries
- Chemicals and biofuels
Rotterdam Vision: CO₂ Hub of Northwest Europe

- Europe will need CCS to meet climate targets
  - Not only in power, but essential in industry
- CO₂ hubs will strengthen sustainable economic growth at lower costs
- Rotterdam is ideal place in North-west Europe: “Gateway to 350 mln. customers”
- ROAD is the next step
ROAD | Maasvlakte CCS Project C.V.

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