HISTORY OF K12-B

A CO₂ injection demonstration project

Vincent Vandeweijer
HIGHLIGHTS OF K12-B

- First site in the world where CO₂ is being injected into the same reservoir from which it originated
- First and only operational CO₂ storage project in the Netherlands
- Serves as field laboratory on a fully productive gas platform in the Southern North Sea
- CO₂ injection performed on the mature, still producing natural gas field K12-B
- 12 years of capturing and re-injection of CO₂ without any major incidents

- Long term ongoing scientific research
- Close collaboration between operator and research institutes
CCS IN NORTH SEA

- Major part CO$_2$ storage capacity of Europe lies in the North Sea
- Countries around the North Sea: Limited onshore storage*
- Shorter term: share infrastructure to support CCS development in North Sea countries
- Medium / longer term: joint transport and storage infrastructure
SHORT TERM STORAGE CAPACITIES DUTCH SECTOR

Gas fields (clusters)

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>K15</td>
<td>54 Mt (165)</td>
<td>&gt;2016</td>
</tr>
<tr>
<td>K08</td>
<td>130 Mt (195)</td>
<td>&gt;2019</td>
</tr>
<tr>
<td>L10</td>
<td>125 Mt (175)</td>
<td>&gt;2022</td>
</tr>
<tr>
<td>K05</td>
<td>40 Mt (140)</td>
<td>&gt;2028</td>
</tr>
</tbody>
</table>

Saline formations

<table>
<thead>
<tr>
<th>Location</th>
<th>Size</th>
<th>Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cretac.</td>
<td>225 Mt</td>
<td>2015+</td>
</tr>
<tr>
<td>Cretac.</td>
<td>360 Mt</td>
<td>2025+</td>
</tr>
<tr>
<td>Trias</td>
<td>650 Mt</td>
<td>2025+</td>
</tr>
<tr>
<td>Rotlieg.</td>
<td>60 Mt</td>
<td>2025+</td>
</tr>
<tr>
<td>Trias</td>
<td>190 Mt</td>
<td>2025+</td>
</tr>
</tbody>
</table>
HOW DID THE CO₂ INJECTION START

- On 7 February 2002, the Dutch Minister of Economic Affairs introduced a new policy to promote studies into the feasibility of CO₂ storage in the subsurface.
- Through CRUST: CO₂ Re-use through Underground Storage under the Dutch Climate Policy Implementation Plan, funding became available for studies that would evaluate the feasibility and use of underground CO₂ injection, including the associated infrastructure and organizational aspects.
- In that same year a feasibility study was kicked off. The project’s aim was to investigate the feasibility of CO₂ injection and storage in depleted natural gas fields on the Dutch continental shelf.
- K12-B, a mature gas field, was selected as a demonstration site for offshore injection of CO₂.
- The project was subsidized by the Dutch Ministry of Economic Affairs and carried out by Gaz de France Production Nederland B.V., the operator of the K12-B platform and TNO.
LOCATION AND SIZE

- Gas field in the Dutch sector of the North Sea
- 150 km North West of Amsterdam
- 8 km long & 2.5 km wide
LOCATION AND SIZE

Overlay of the field as reference*
THE FEASIBILITY STUDY

Aim was to investigate the feasibility of CO₂ re-injection and storage

- With the Dutch government it was agreed that the study would address the following key aspects:
  - Legal, regulatory and social aspects
  - Necessary surface and sub-surface equipment
  - Expected behaviour of the natural gas field
  - Safety, monitoring and environmental aspects
  - Economics of underground injection and storage

- Initial project was performed by Gaz de France and TNO
LEGAL, REGULATORY AND SOCIAL ASPECTS

- Legal and regulatory aspects of underground CO₂ injection and storage have been studied.
- For CO₂ storage at K12-B the following legislations were considered the most relevant:
  - The new (Dutch) Mining Act
  - The Environmental Management Act
  - The OSPAR Convention

- Result: No significant legal or social impediments against the foreseen underground CO₂ injection
- Although some points needed further clarification, like the ownership of the injected CO₂

- Minister of environment visited the K12-B platform during CO₂ injection operations
GEOLOGICAL SETTING

- Gas field in the Upper and Lower Slochteren*
- Aeolian and fluvial sediments
- Permian age
- Zechstein salt seal

- 3900 m Depth
- Compartmentalized
- 128°C
- Low permeability*
GAS PRODUCING OPERATIONS

- Discovered early 80’s, online since 1987
- Initial gas in place: 14.4 BCM
- Currently at tail end production, < 0.2 BCM to go

- Initial CO\textsubscript{2} content of natural gas is 13 %
- Since beginning CO\textsubscript{2} is separated from produced gas

- CO\textsubscript{2} (re-)injection online since 2004

- K12-B platform functions as a hub for natural gas
OVERVIEW OF THE CO₂ INJECTION FACILITIES

- The CO₂ is separated from the natural gas by means of an adsorption process with a solvent*
- A compression unit compressed the CO₂ to approximately reservoir pressure to enable injection
- Full-scale unit would be about 10 to 20 times larger than that of the current demonstration unit
CO₂ INJECTION AT K12-B

- All wells were originally developed as natural gas producers.
- In 2004 actual CO₂ injection started in single well compartment 4*.
  - Investigate injectivity and test the injection facility.
  - Investigate the behavior of CO₂ in the well and the reservoir.
- Over 10 kt were injected using the K12-B8 well.
- Injection continued in 2005 in multi well compartment 3*, additional goals:
  - Investigative well integrity under CO₂ injection conditions*.
  - Investigate possibilities for CO₂ EGR.
- Over 100 kt and counting…. 

19 April 2016
DYNAMIC FLOW MODELS

- History matched models for pressure and flow were created*
- Later also CO$_2$ concentrations in production wells were modelled*
- Various simulators were used and numerous updates were created
  - Including the *seemingly decreased* $kh$ in well K12-B6* (caused by intruding water)
Objective assessing the impact of the CO$_2$ on the well completion materials
The K12-B6 well injector has been used since 2005 for the injection of CO$_2$
The impact of this CO$_2$ on the well has been studied by lowering a variety of monitoring tools
Throughout the measurements no serious issues were detected
Objective: study the migration of CO₂ in the reservoir

- Two tracers were injected in the K12-B6 well at start of CO₂ injection in 2005
- Tracer concentration was measured in the two (three) producers to identify exact breakthrough
- The use of tracers has contributed to an improved understanding of the storage potential and the potential for enhanced gas recovery.
- Currently project on new chemical tracers with slightly different properties to improve interpretation
Well K12-B8 is a gas producer that stopped producing mid-2004.
This well was used end 2004 and early 2005 for the first phase of CO$_2$ injection in the K12-B field (10 months of CO$_2$ injection).

After three years without any activities performed on the well, the well was back produced in 2007.
Measurements were taken (incl. CO$_2$ concentration), providing insights in the behavior of CO$_2$ in the depleted gas reservoir.

Experiment was later repeated with comparable results.
TIMELINE CO₂ INJECTION K12-B

- **2002**: Start CO₂ injection project
- **2003**: Start of CO₂ injection & tracer injection & log suite
- **2004**: Integrity Logs
- **2005**: Various downhole measurements
- **2006**: Monitoring K12-B Project
- **2007**: Downhole water/gas samples
- **2008**: Integrity Logs
- **2009**: Integrity Logs
- **2010**: Downhole scale Samples & analysis
- **2011**: Various downhole measurements
- **2012**: Well Operations
- **2013**: Permits in place for injection of new tracers
- **2014**: Design new tracers finished
- **2015**: EC CO₂ Remove Project
- **2016**: EC CO₂ CARE Project

Projects:
- **TKI Innovative Tracer Project**
- **TKI Restoring the Seal Project**
- **Feasibility Study**
- **Phase 1 desk study**
- **Phase 2 Offshore re-injection of CO₂ Project**
- **CATO2 Project**
- **TKI Innovative Tracer Project**

Timeline:
- **2002**: Start CO₂ injection project
- **2003**: Start of CO₂ injection & tracer injection & log suite
- **2004**: Integrity Logs
- **2005**: Various downhole measurements
- **2006**: Monitoring K12-B Project
- **2007**: Downhole water/gas samples
- **2008**: Integrity Logs
- **2009**: Integrity Logs
- **2010**: Downhole scale Samples & analysis
- **2011**: Various downhole measurements
- **2012**: Well Operations
- **2013**: Permits in place for injection of new tracers
- **2014**: Design new tracers finished
- **2015**: EC CO₂ Remove Project
- **2016**: EC CO₂ CARE Project

Projects:
- **TKI Innovative Tracer Project**
- **TKI Restoring the Seal Project**
- **Feasibility Study**
- **Phase 1 desk study**
- **Phase 2 Offshore re-injection of CO₂ Project**
- **CATO2 Project**
- **TKI Innovative Tracer Project**
CONCLUSIONS AND OUTLOOK

- It is technically feasible to re-inject CO$_2$ in a safe way into depleted gas fields, and it can also be done simultaneous with E&P operations.
- There is now a proven track record of over a decade, supported by many risk assessment studies.
- The findings of this extensive scientific CO$_2$ re-injection research can be showcased and applied to other Carbon Capture and Storage Projects in the world.
CONCLUSIONS AND OUTLOOK

- Modelling, monitoring and injection of innovative tracers
  - Permits arranged
  - Injection of tracers is planned for May

- Experiment to restore the original natural salt seal by removal of part of the casing
ACKNOWLEDGEMENTS

- The Dutch government for supporting the ORC, Castor, MONK, CATO, CATO2 and TKI projects
- The European Union for supporting the EC CO2ReMoVe and EC CO2Care projects
- Daan D’Hoore en Hilbrand Graven from ENGIE (formerly GdF) for all their support over the years
THANK YOU FOR YOUR ATTENTION
WELL INTEGRITY

- CBL could not be performed due to obstruction at perforation level**
- Obstruction was investigated with a video log
- EMIT (ElectroMagnetic Imaging Tool) insensitive to scale
WELL INTEGRITY

- CBL could not be performed due to obstruction at perforation level**
- Obstruction was investigated with a video log
- EMIT (ElectroMagnetic Imaging Tool) insensitive to scale
- Ran in combination with Multi-finger caliper (PMIT) and Gamma Ray*
- Conclusion was no relevant issues with the wells

- In addition to wireline logs and memory gauges also downhole water samples were taken and analyzed*