HISTORY OF K12-B

A CO_2 injection demonstration project

Vincent Vandeweijer

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ENGIE by people for people

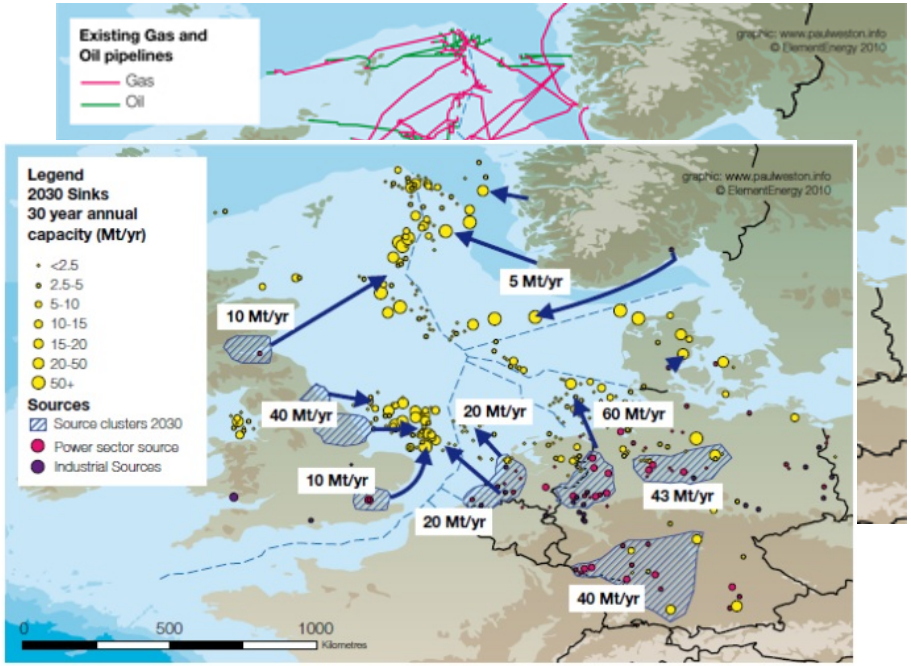
HIGHLIGHTS OF K12-B

- First site in the world where CO_2 is being injected into the same reservoir from which it originated
- First and only operational CO_2 storage project in the Netherlands
- Serves as field laboratory on a fully productive gas platform in the Southern North Sea
- CO_2 injection performed on the mature, still producing natural gas field K12-B
- 12 years of capturing and re-injection of CO_2 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



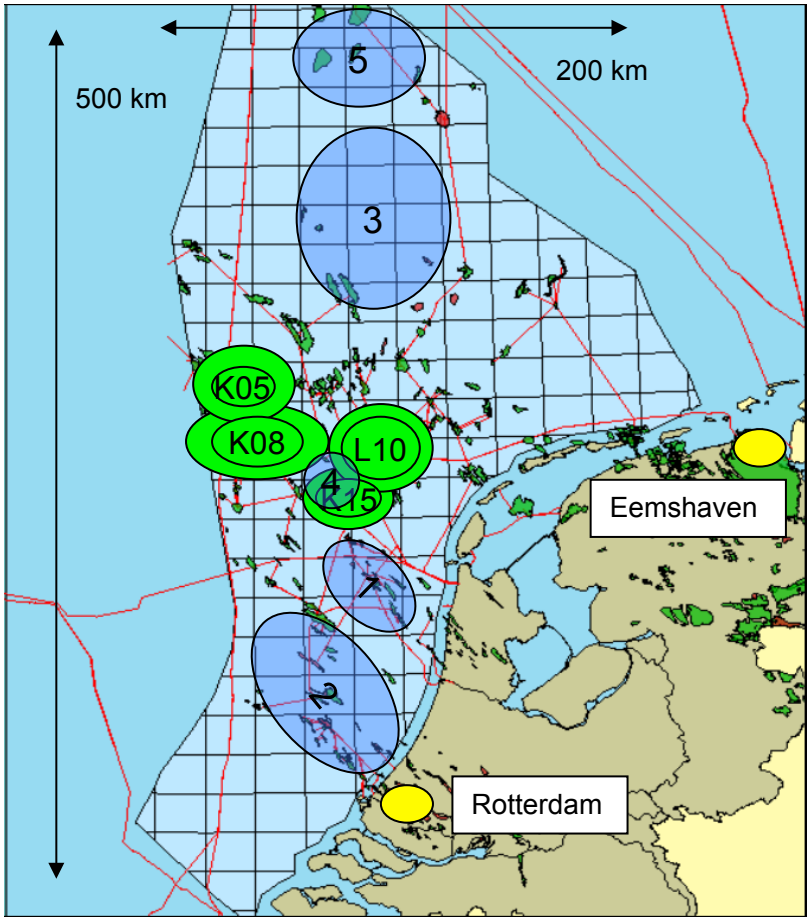
SHORT TERM STORAGE CAPACITIES DUTCH SECTOR

Gas fields (clusters)

Name	Size	Available
K15	54 Mt (165)	>2016
K08	130 Mt (195)	>2019
L10	125 Mt (175)	>2022
K05	40 Mt (140)	>2028

Saline formations

Location	Size	Available
1. Cretac.	225 Mt	2015+
2. Cretac.	360 Mt	2025+
3. Trias	650 Mt	2025+
4. Rotlieg.	60 Mt	2025+
5. Trias	190 Mt	2025+



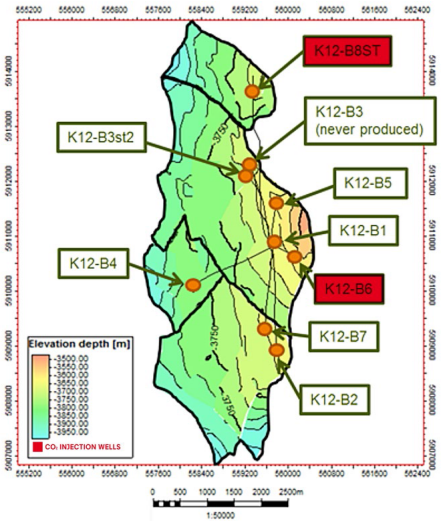
HOW DID THE CO_2 INJECTION START

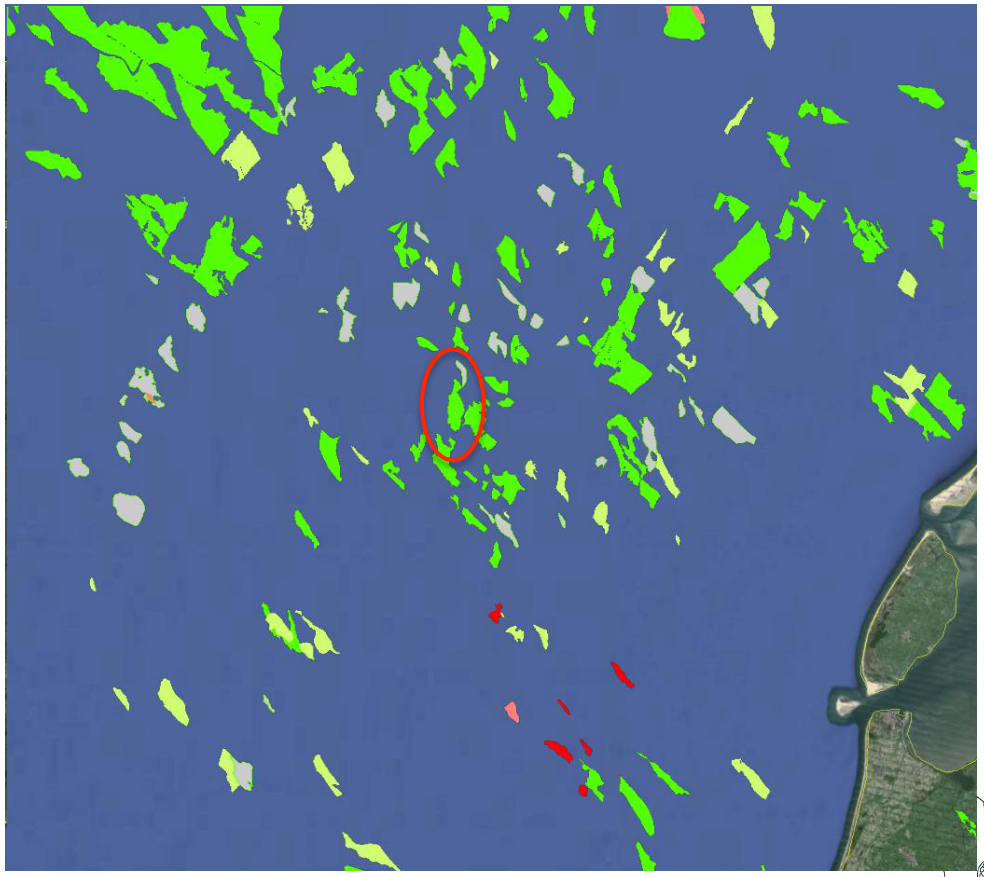
- On 7 February 2002, the Dutch Minister of Economic Affairs introduced a new policy to promote studies into the feasibility of CO_2 storage in the subsurface
- Through CRUST: CO_2 Re-use through Underground Storage under the Dutch Climate Policy Implementation Plan, funding became available for studies that would evaluate the feasibility and use of underground CO_2 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 CO_2 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 CO_2
- 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

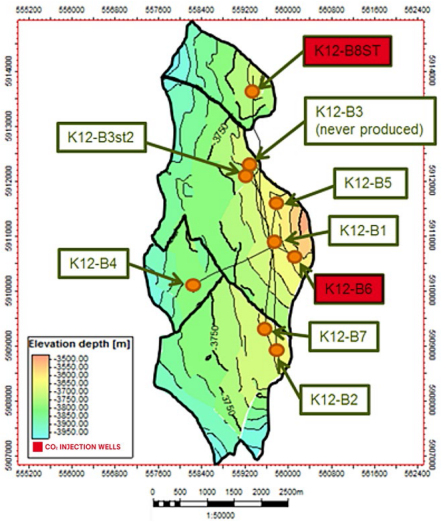
- Gas field in the Dutch sector of the North Sea
- 150 km North West of Amsterdam
- 8 km long & 2.5 km wide

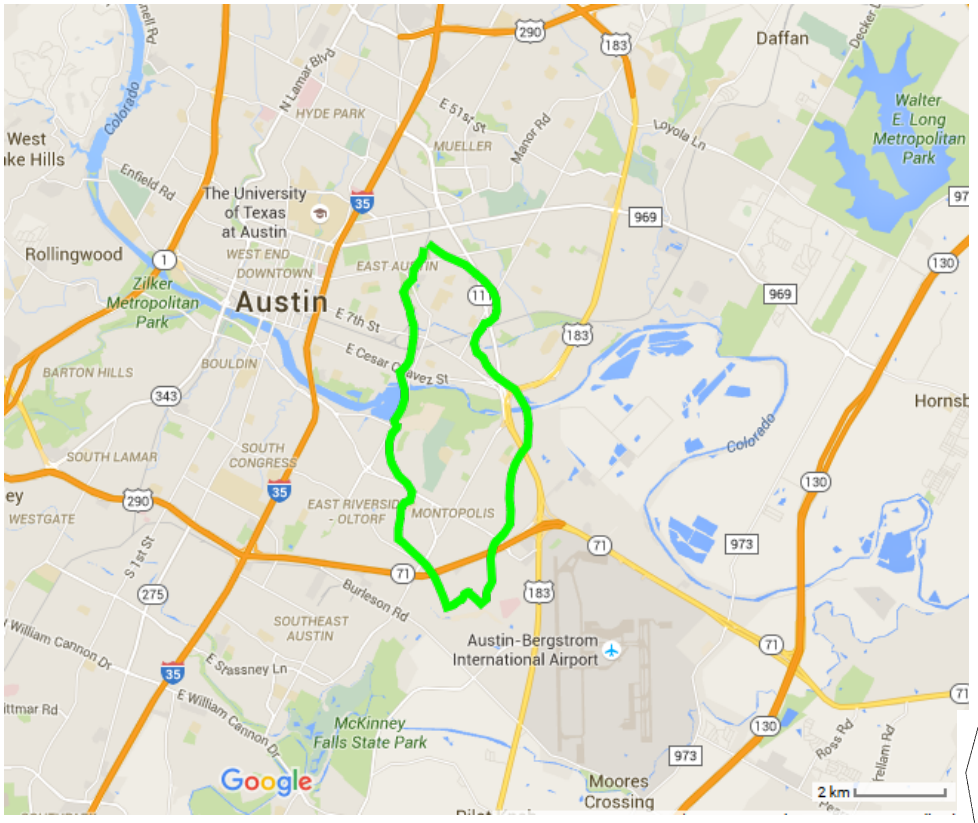




LOCATION AND SIZE

- Overlay of the field as reference*





THE FEASIBILITY STUDY

Aim was to investigate the feasibility of CO_2 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

Gaz de France

TNO

LEGAL, REGULATORY AND SOCIAL ASPECTS

- Legal and regulatory aspects of underground CO_2 injection and storage have been studied.
- For CO_2 storage at K12-B the following legislations were considered the most relevant:
  - The new (Dutch) Mining Act
  - The Environmental Management Act
  - The OSPAR Convention

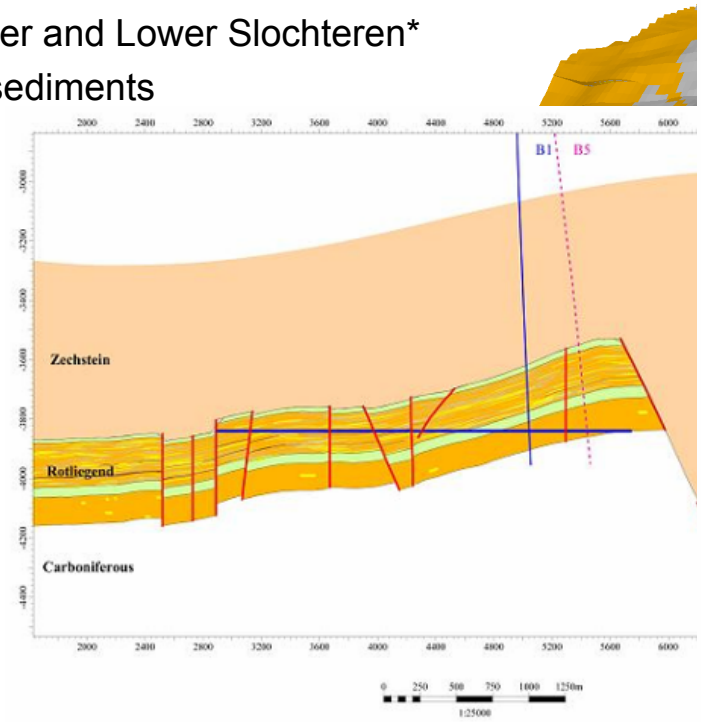
- Result: No significant legal or social impediments against the foreseen underground CO_2 injection
- Although some points needed further clarification, like the the ownership of the injected CO_2

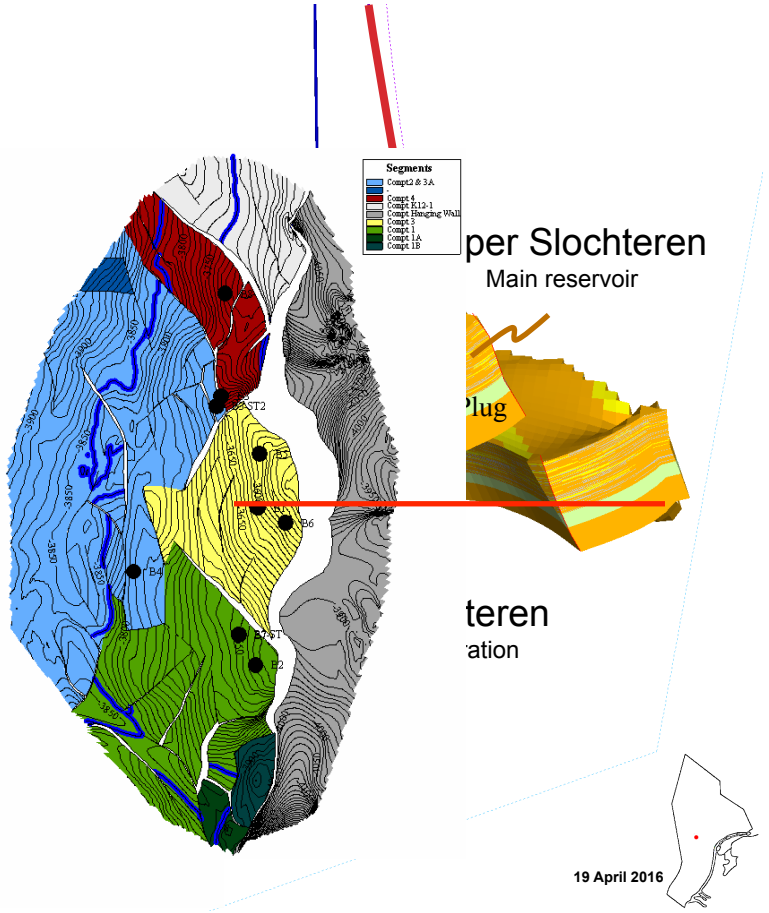
- Minister of environment visited the K12-B platform during CO_2 injection operations

GEOLOGICAL SETTING

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

- 3900 m Depth
- Compartmentalized
- 128ºC
- Low permeability*





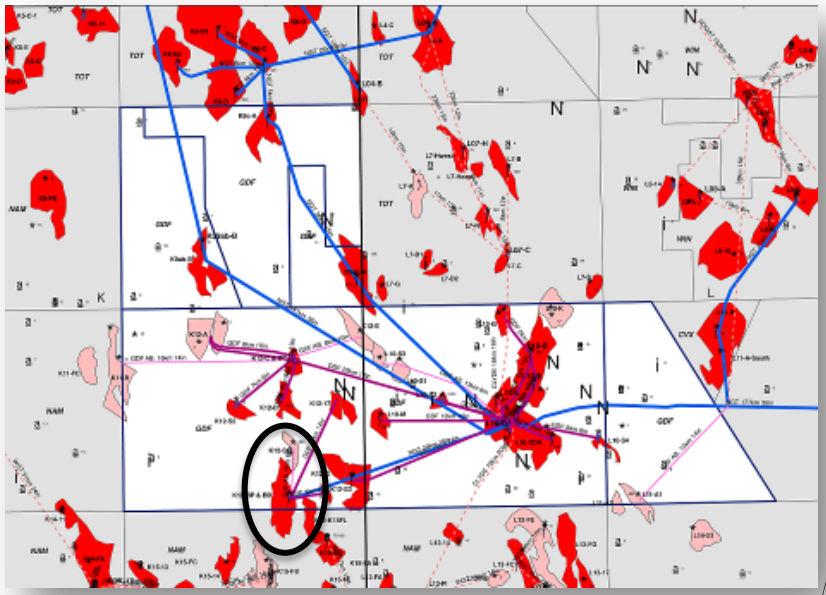
GAS PRODUCING OPERATIONS

- 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_2 content of natural gas is 13 %
- Since beginning CO_2 is separated from produced gas

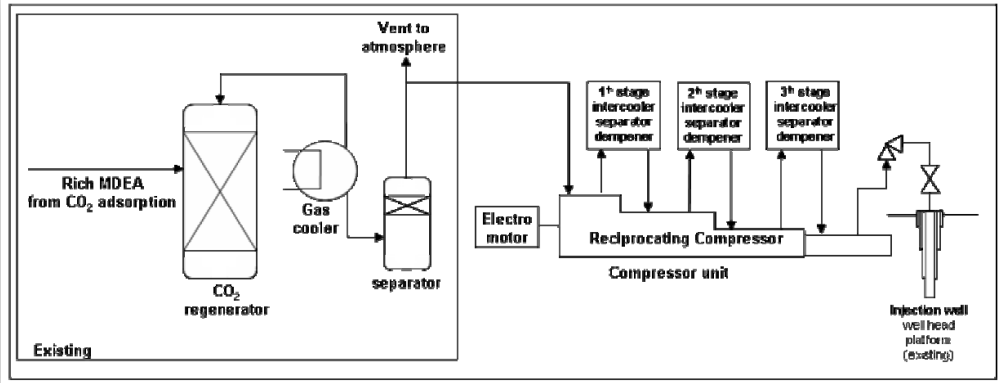
- CO_2 (re-)injection online since 2004

- K12-B platform functions as a hub for natural gas



OVERVIEW OF THE CO_2 INJECTION FACILITIES

- The CO_2 is separated from the natural gas by means of a adsorption process with a solvent*
- A compression unit compressed the CO_2 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

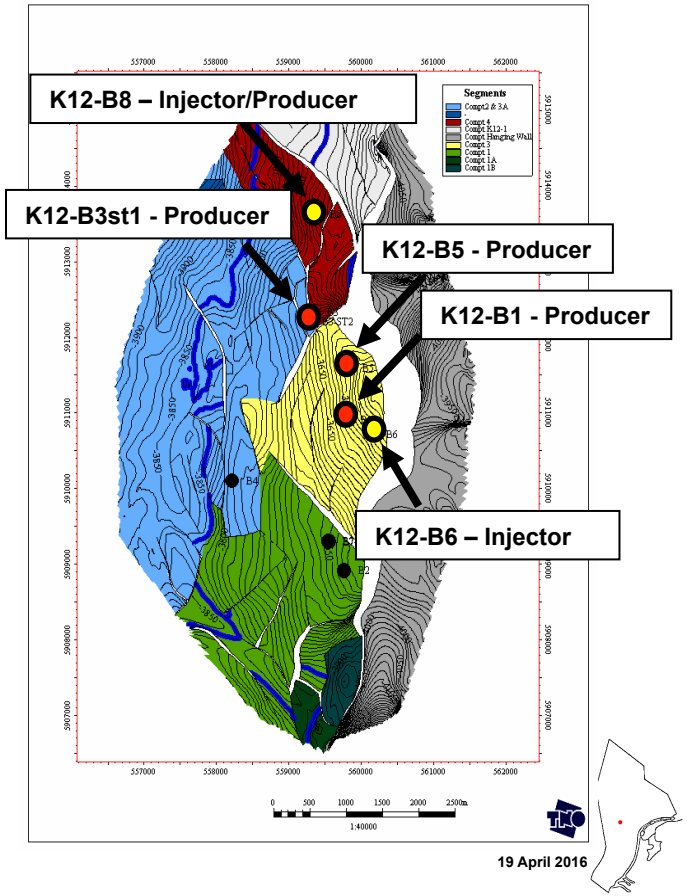


CO_2 INJECTION AT K12-B

- All wells were originally developed as natural gas producers

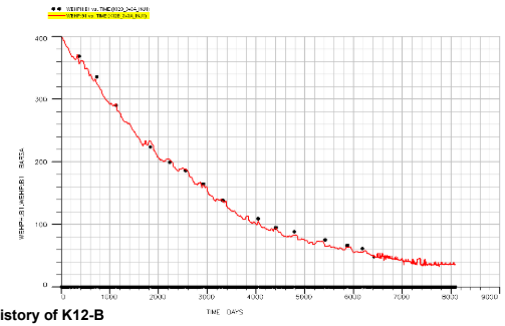
- In 2004 actual CO_2 injection started in single well compartment 4*
  - Investigate injectivity and test the injection facility
  - Investigate the behavior of CO_2 in the well and the reservoir
- Over 10 kt were injected using the K12-B8 well

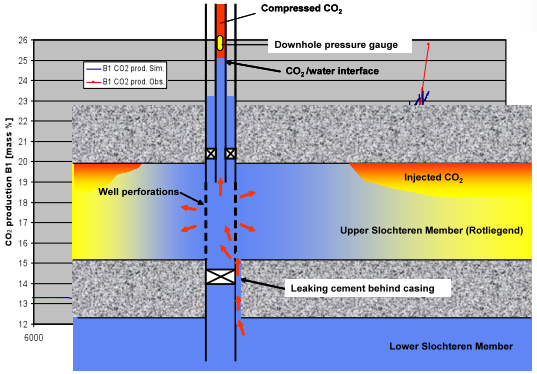
- Injection continued in 2005 in multi well compartment 3*, additional goals:
  - Investigative well integrity under CO_2 injection conditions*
  - Investigate possibilities for CO_2 EGR
- Over 100 kt and counting….

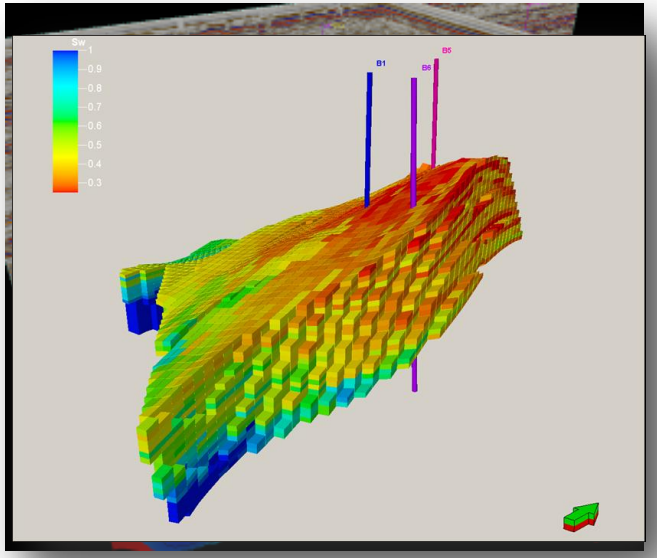


DYNAMIC FLOW MODELS

- History matched models for pressure and flow were created*
- Later also CO_2 concentrations in production wells were modelled*
- Various simulators where used and numerous updates were created
  - Including the *seemingly decreased* kh in well K12-B6* (caused by intruding water)

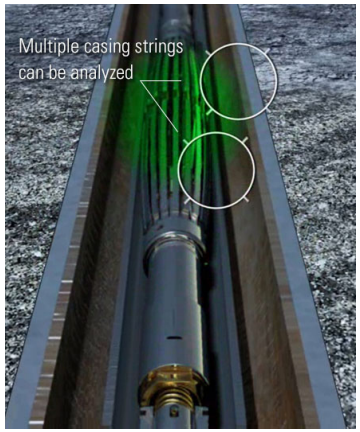


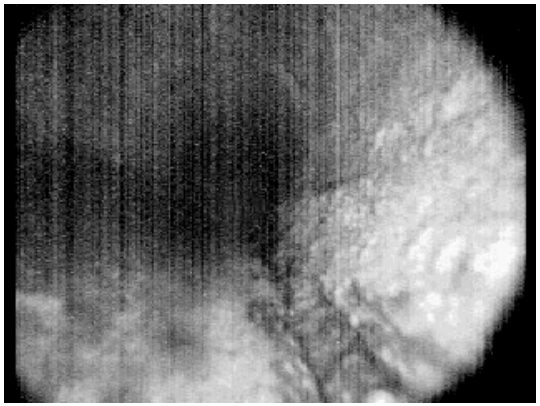




WELL INTEGRITY

- 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

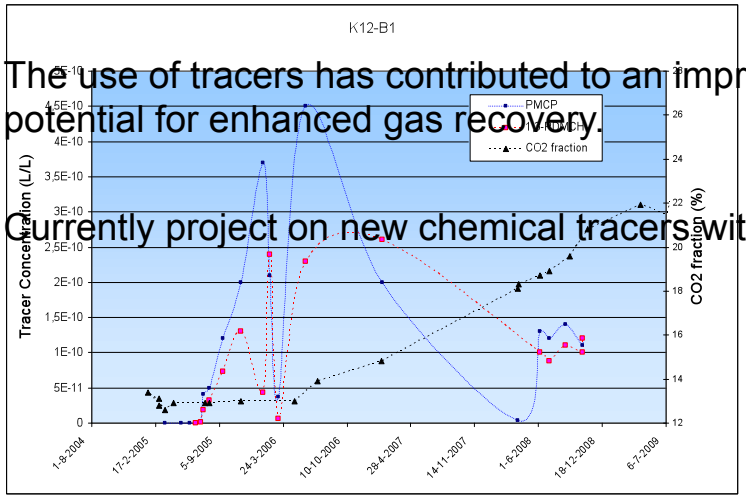


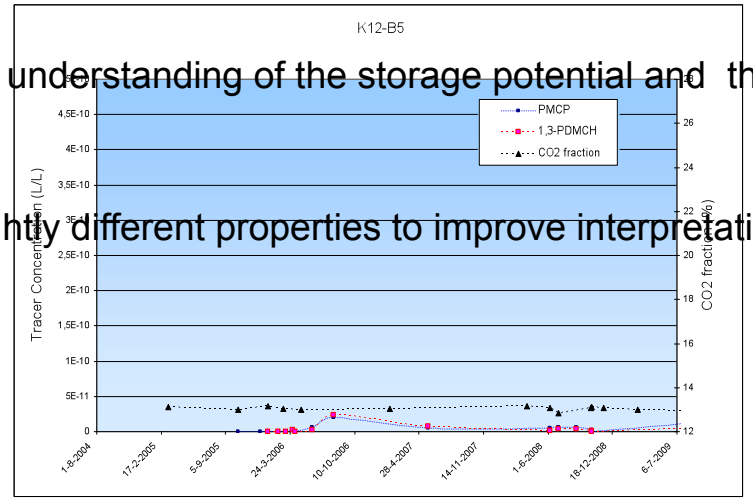


CHEMICAL TRACERS

Objective: study the migration of CO_2 in the reservoir

- Two tracers were injected in the K12-B6 well at start of CO_2 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

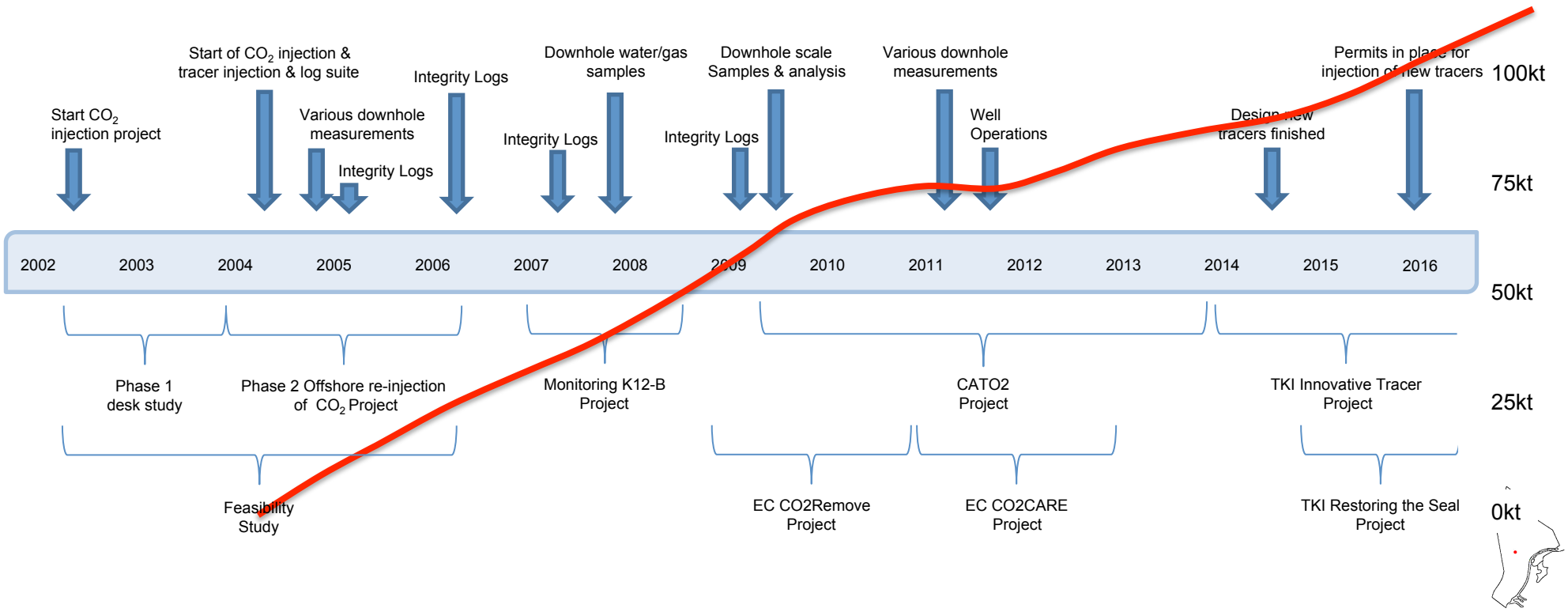
BACK PRODUCTION INJECTED CO_2

- 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 CO_2 INJECTION K12-B



CONCLUSIONS AND OUTLOOK

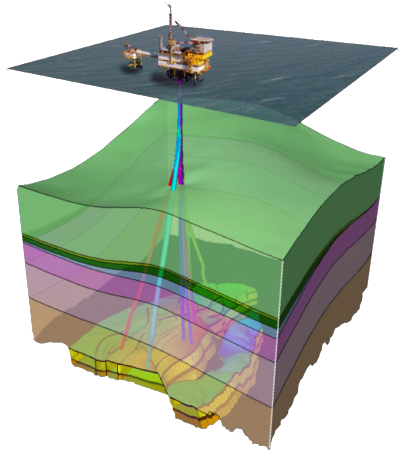
- **It is technically feasible to re-inject CO_2 in a safe way into depleted gas fields, and it can also be done simultaneous with E&P operations**
- There is now a proven track record of over a decade, supported by many risk assessment studies
- The findings of this extensive scientific CO_2 re-injection 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
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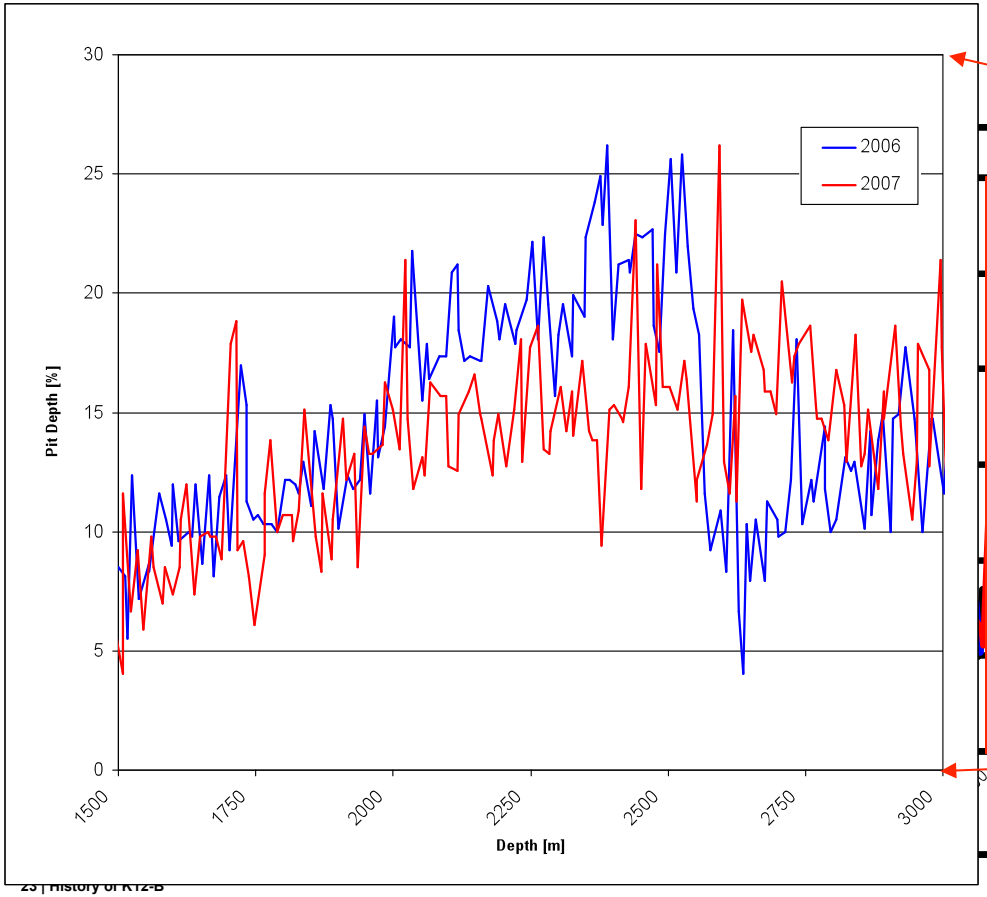
30
25
20
15
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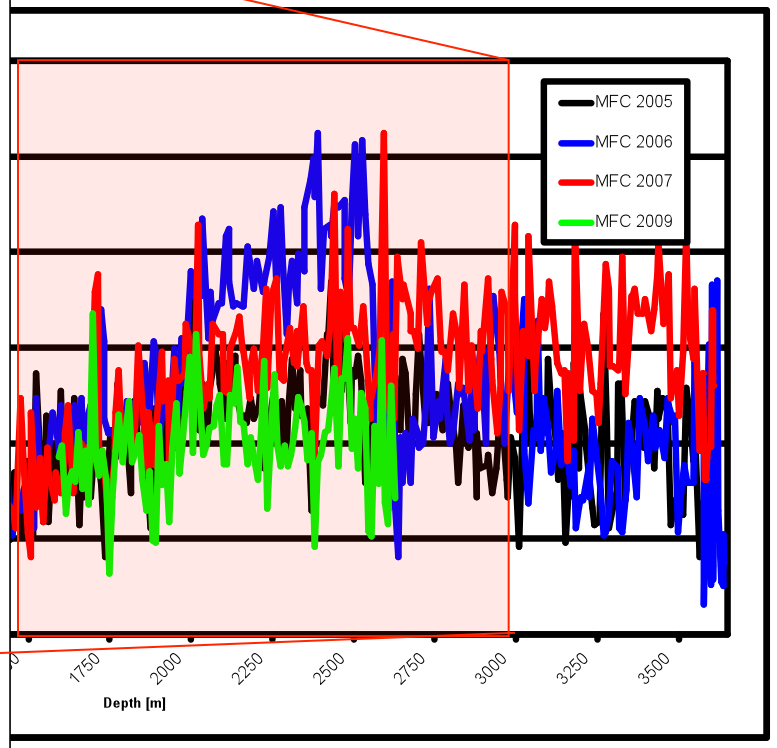
MFC 2005
MFC 2006
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1750
2000
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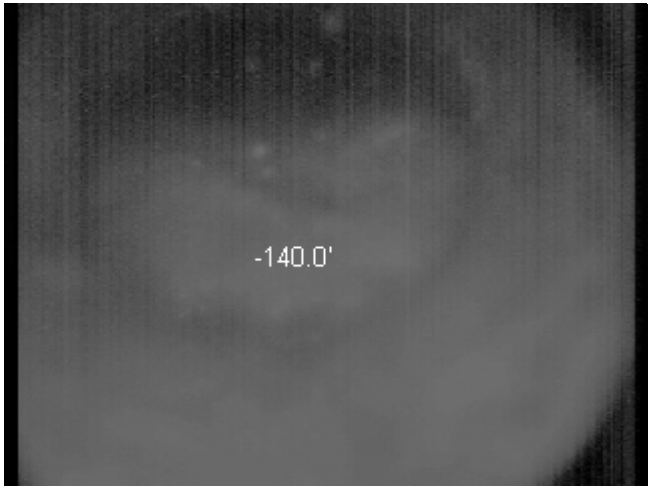
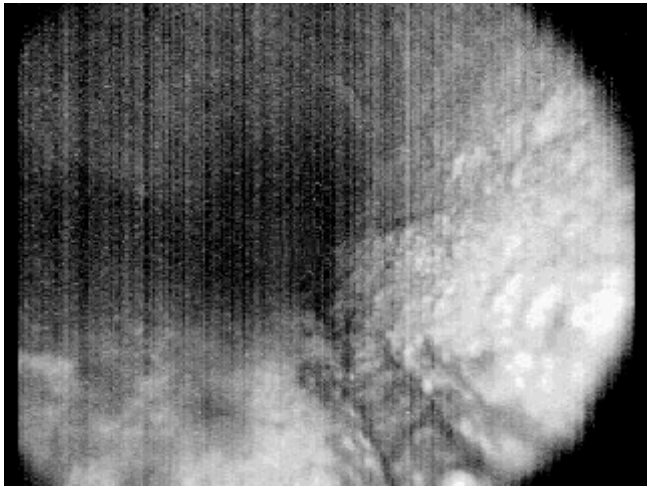
Depth [m]

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*

CATIONS		mg/l	meq/l
Sodium	Na	93150	4052
Potassium	K	918	23
Calcium	Ca	13300	664
Magnesium	Mg	2156	177
Barium	Ba	6.1	0.09
Strontium	Sr	184	4.2
Iron (tot.)	Fe	274	9.8
Iron (diss.)	Fe	245	8.8
ANIONS		**mg/l**	**meq/l**
Chloride	Cl	172884	4876
Sulphate	SO_4	358	7.5
Bicarbonate	HCO3	233	3.8
Carbonate	CO3	nil	nil
Hydroxide	OH	nil	nil

PROPERTIES	
pH @ 20°C	6.10
Specific Gravity @ 15.6°C	1.186
Resistivity@15.6°C (Ohm.m)	0.044
Dissolved solids (g/l)	281.4
H_2S Content	not detected

ADDITIONAL ELEMENTS		mg/l
Lithium	Li	40
Silicon	Si	20
Phosphorus	P	< 7
Boron	B	76
Aluminium	Al	< 6