

Geological Storage of CO₂

Ketzin Pilot Site

Carbon dioxide (CO₂) is a greenhouse gas. Increasing CO₂ content in the atmosphere and its relevance to global climate change have motivated scientists to look for ways to reduce emissions of this gas. Together with energy-saving measures, increases in energy efficiency and the development of renewables, CCS (carbon capture and storage) technology, involving the capture, transport and storage of CO₂, can make a critical contribution here.

Since 2004, scientists of the GFZ German Research Centre for Geosciences have been working on the storage of CO₂ in deep geological formations. Ketzin, in the German State of Branden-

burg, was chosen as a pilot site. For the purposes of research, all phases of a CO₂ storage project have been implemented on this site, and the following objectives have been achieved:

- *The reservoir processes due to CO₂ injection and migration are being studied from a scientific and engineering perspective.*
- *Site behaviour during the operational and closure phases has been and continues to be analysed.*
- *Scientific understanding of geological storage of CO₂ is being advanced.*

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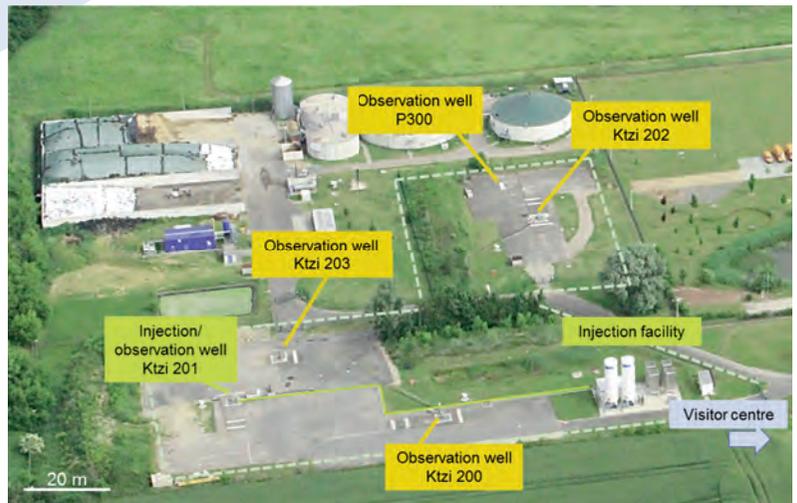


GEOLOGICAL STORAGE OF CARBON DIOXIDE

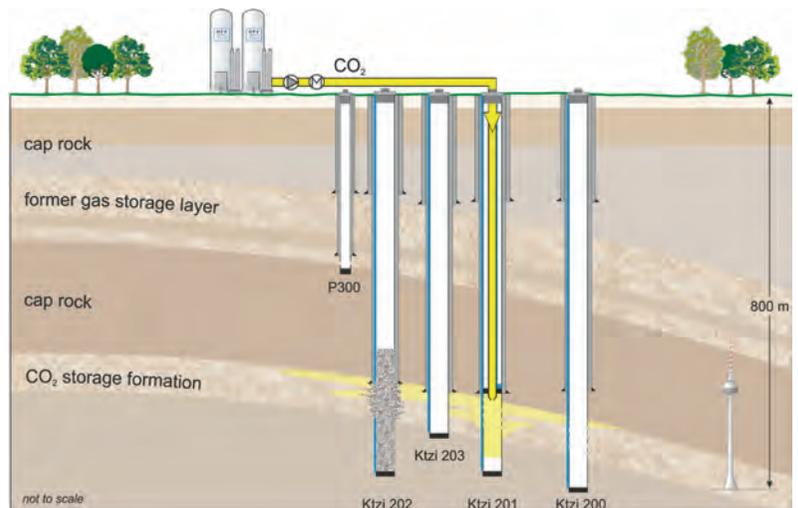
The Ketzin pilot site in Brandenburg

Geological storage of CO₂ is the subject of a research project being undertaken in the vicinity of the town of Ketzin, west of Berlin. The geological formations used for this purpose lie at a depth of 630 m to 650 m and consist of porous sandstone capable of trapping the CO₂ in the rock pores. Rock formations of this kind are widely distributed throughout the North German Basin. At Ketzin, these sandstone strata are not horizontally aligned, but bulge upwards forming a dome-like structure. These reservoir formations are sealed by more than 165 m of overlying shaly cap rocks. Together with the dome-like structure, these cap rocks ensure controlled and limited migration of the CO₂.

The Ketzin site was used for the seasonal storage of town gas and later natural gas until 2000 at a depth of around 280 m. For this reason, the Ketzin site has been thoroughly surveyed: numerous data and boreholes from previous investigations provide information on the geology. It was on this basis, and that of additional investigations, that the first three deep wells were drilled to a depth of around 800 m in 2007 for the research project: Ktzi 201 for injection and observation of the CO₂ and Ktzi 200 and Ktzi 202 for the observation of the CO₂ migration. In order to achieve a more extensive examination of the zone overlying the stored CO₂, the shallower borehole P300 was drilled in 2011. The well Ktzi 203 was drilled in 2012 to a depth of 700 m. The main objective of this borehole was the extraction of rock samples from the cap rock and reservoir, respectively, the latter having been in contact with the injected CO₂ for around four years.



Aerial photo of the Ketzin pilot site



Schematic vertical profile of the Ketzin pilot site including the injection facility and the wells. The well Ktzi 202 was partially closed in autumn 2013. For comparison: the Berlin television tower (368 m height).

Along with the GFZ, the research work has involved partners from universities in Germany and abroad, research institutes and industrial and medium-sized companies. From its inception, the project has been under the supervision of the approval authority, the State Agency for Mining, Geology and Raw Materials (LBGR) of the State of Brandenburg, and the project has received support from the town of Ketzin.

2004-2007

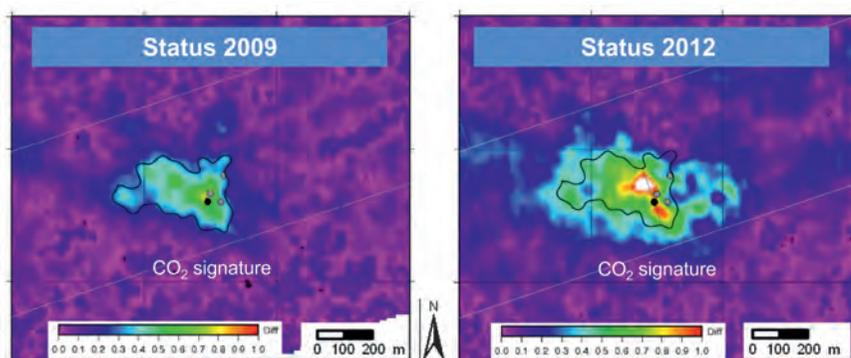
- 04/04 Start of CO₂SINK project
- 09-11/05 3D seismic baseline measurement
- 01/06 Ground investigation
- 03-10/07 Drilling of wells Ktzi 200, 201 and 202
- 11/07-04/08 Geophysical baseline measurements

2008

- 02 Cold start of the injection facility
- 04 Commissioning of the scientific container
- Start of injection 30-06-2008
- 07 Arrival of the CO₂ in the well Ktzi 200
- 08-11 Geophysical repeat measurements

2009/2010

- 03/09 Arrival of the CO₂ in the well Ktzi 202
- 10/09 Inspection of the wells with a film camera
- 05/09+09-11/09 Geophysical repeat measurements
- 03/10 Installation of manometer and riser tubing for gas monitoring
- 09/10 Start of CO₂MAN project



Using baseline and repeat measurements, geophysical methods provide a clear signature of the CO₂ distribution in the storage formation. Seismic measurements for example show the changes in the elastic properties of the reservoir due to the CO₂ injection. After injection of approximately 22,000 tonnes and 61,000 tonnes of CO₂, respectively (2009 vs. 2012) the CO₂ could be imaged with a maximum east-west extension of 700 m in 2012 (black dot = injection well).

Operation, monitoring and associated modelling

Injection of CO₂ at the Ketzin pilot site began in 2008 and ended in August 2013. During this time, a total of 67,271 tonnes of CO₂ were safely and reliably injected. The CO₂ in question was mainly of food quality (purity > 99.9%). In addition, in 2011 approximately 1,500 tonnes of CO₂ from the pilot capture facility “Schwarze Pumpe” (power plant CO₂ with purity > 99.7%) was used for injection purposes, and in summer 2013 injection of a mix of 95% CO₂ and 5% N₂ was tested. These tests represent further important steps in the implementation of the entire CCS chain consisting of capture, transport and storage of CO₂.

The scientific investigations accompanying the CO₂ storage project in Ketzin comprise both permanent and periodic measurements, as below:

- Permanent temperature and pressure monitoring in the boreholes

- Geophysical and geochemical measurements in the boreholes and from ground surface level
- Logging campaigns
- Measurement of naturally occurring CO₂ fluxes at ground surface level (soil respiration)
- Analyses of rock samples, gases and liquids from a variety of depths

The monitoring methods in Ketzin are among the most comprehensive applied anywhere in the world in the field of CO₂ storage. This work is supplemented by computer-supported models. These have enabled the following to be achieved:

- The migration of the CO₂ in the reservoir can be monitored and predicted.
- The processes in the reservoir and the cap rock strata can be accurately described.
- The integrity of the reservoir and cap rock can be assessed.

2011

- 03 Logging campaign
- 03 Geophysical repeat measurements
- 04-05 Reconstruction of the visitor centre
- 05 Injection of CO₂ from “Schwarze Pumpe”
- 06-08 Drilling of observation well P300

2012

- 01 Aquifer test in well P300
- 06-09 Drilling of observation well Ktzi 203
- 09-11 3D seismic repeat measurement
- 10 Logging campaign

2013/14 & Future

- End of CO₂ injection 29-08-2013 (67,271 t)
- 10 Partial closure of well Ktzi 202
- 12 Dismantlement of the injection facility
- 01/14 Start of COMPLETE project
 - Continuation of monitoring as well as research and development
 - Stepwise closure of all wells

The Ketzin pilot site covers all aspects of the development and the operation of a storage site.

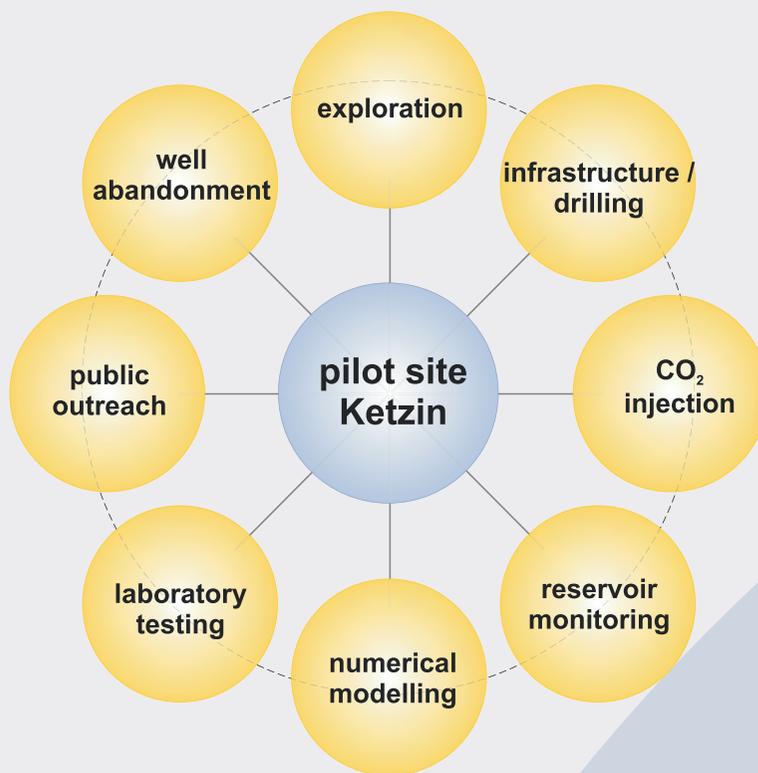
Results

The work and scientific investigations so far undertaken at the Ketzin pilot site have been successful. They have resulted in significant findings relating to geological CO₂ storage in deep saline aquifers. The results bear out the following:

- Geological storage of CO₂ at the Ketzin pilot site has so far proceeded in a safe and reliable manner and has been risk-free with regards to human health and environmental concerns.
- An appropriate combination of different geochemical and geophysical monitoring methods is able to detect even small quantities of CO₂ and map their spatial extent.
- The interactions between fluids and rock at the Ketzin pilot site which are caused by the injected CO₂ have no significant effects on the integrity of the reservoir and cap rock.
- Computer simulations can reproduce the temporal and spatial behaviour of the injected CO₂, and are suitable tools to predict the long-term behaviour of the reservoir.

The final phase of the Ketzin project has started

The Ketzin pilot site represents more than five years' experience in operating a CO₂ reservoir. Since CO₂ injection ceased in August 2013, further investigations relating to the monitoring and behaviour of the reservoir are now being conducted in order to make a final evaluation of the technology.



Moreover, the boreholes are being successively abandoned, while monitoring is continuing. The aim is that Ketzin will be the first CO₂ reservoir, in pilot scale, which completes its full life cycle, thereby providing first-hand experience in respect of the closure of such a site.

The information centre at the Ketzin pilot site

Public relations are a central component of the Ketzin project. The main contact point in this respect is the information centre at the pilot site itself. There visitors can find out about the current results and talk to the scientists, who will explain the context of the CO₂ storage project and the investigation methods used. Visits can be booked via co2ketzin@gfz-potsdam.de

For more information, please visit: <http://www.co2ketzin.de>