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# Underground Storage of $CO_2$

## The Ketzin Pilot Site

*Carbon dioxide ($CO_2$) is a greenhouse gas. The increasing concentration of $CO_2$ in the atmosphere and its relevance to global climate change is motivating scientists to find options for reducing greenhouse gas emissions. Besides energy conservation, methods to maximize energy efficiency and the use of renewable energies – CCS (Carbon Capture and Storage) can help to meet the challenge of minimizing global climate change.*

*At the GFZ German Research Centre for Geosciences, research has been done on the storage of $CO_2$ in deep-seated subsurface reservoirs as part of both European and national projects (including $CO_2$SINK and $CO_2$MAN) since 2001. Ketzin (Brandenburg) was chosen as a pilot site. Since 2008, $CO_2$ has been injected into the reservoir at Ketzin, in order to*

- *improve the scientific understanding of the geological storage of $CO_2$, and*
- *study the subsurface processes of the $CO_2$ injection and distribution.*


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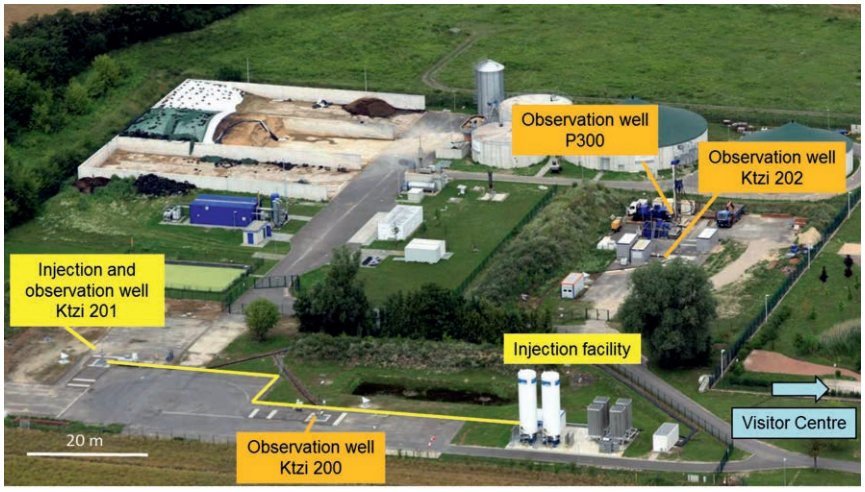
## The Ketzin pilot site in Brandenburg

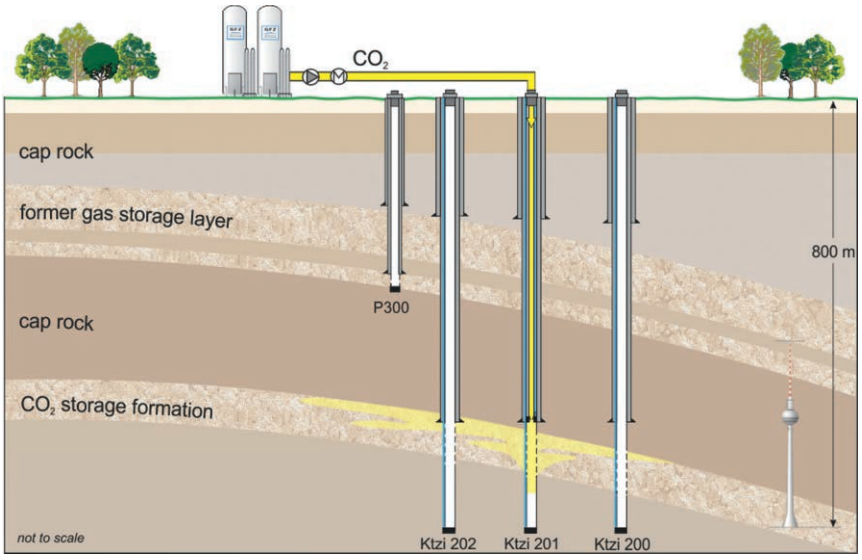
The subsurface storage of $CO_2$ is studied near the town of Ketzin/Havel, just west of Berlin. In this area, formations suitable for storage are found at depths of 630 to 650 m. The targeted reservoir is a porous sandstone of the Stuttgart Formation, which can accommodate $CO_2$ in the pore spaces. This formation is widely present in the North German Basin. At Ketzin, the layers are arched into an underground dome-like structure (called an anticline). Injection of the $CO_2$ takes place at the southern flank of the anticline, at about 630 to 650 m depth. The reservoir is sealed by 210 m thick shaly cap rocks. These cap rocks, together with the anticlinal structure, ensure a controlled and limited distribution of the $CO_2$.

Up until 2004, natural gas was stored in a sandstone formation at about 280 m depth. The Ketzin anticline is therefore well studied. Numerous existing data and boreholes provide information on the geological situation and the properties of the formations. Based on this prior knowledge and later exploratory investigations, three additional wells were drilled for $CO_2$ storage, to depths of about 800 m, in 2007. One of these wells (Ktzi 201) is used for injection and observation of the $CO_2$, while the other two (Ktzi 200 and Ktzi 202) serve as observation wells for monitoring the subsurface distribution of the $CO_2$.

Project partners of the GFZ include national and international universities, research centres, industry and medium-sized companies. The work at the pilot site is supported by the town of Ketzin/Havel, and the regulatory authority has been involved since the start of the project.




*Aerial photo of the Ketzin pilot site*




*Schematic vertical profile of the Ketzin pilot site including the wells. The dome-like structure of the layers is indicated. For comparison: the Berlin television tower (368 m height)*

### 2004-2007

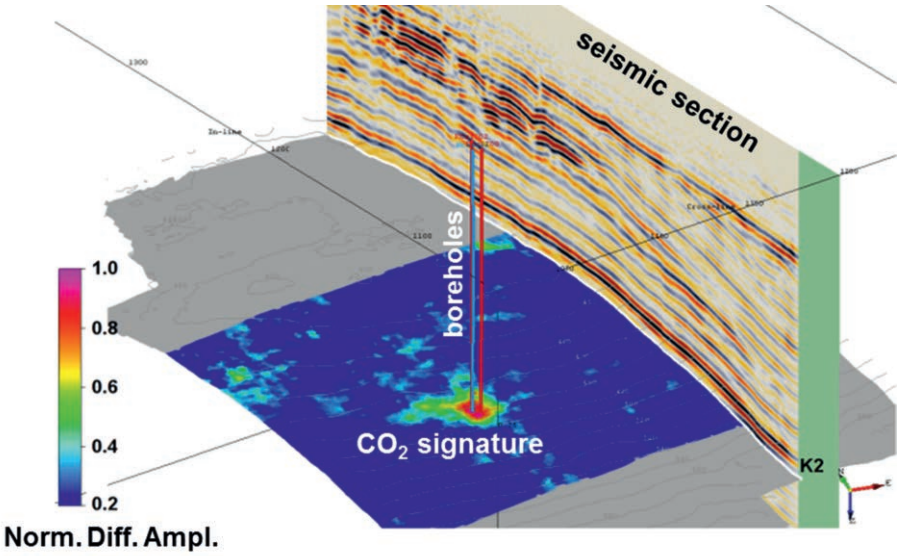
- **04/04** Start of $CO_2$SINK project
- **09-11/05** 3D seismic baseline measurement
- **01/06** Ground investigation
- **03-10/07** Drilling of wells Ktzi 200, 201 and 202
- **11/07-04/08** Geophysical baseline measurements

### 2008

- **02** Cold start of the injection facility
- **04** Commissioning of the scientific container
- **06** Start of injection 30-06-2008
- **07** Arrival of the $CO_2$ in the well Ktzi 200
- **08-11** Geophysical repeat measurements

### 2009

- **03** Arrival of the $CO_2$ in the well Ktzi 202
- **03** 10,000 t $CO_2$ injected
- **08** 20,000 t $CO_2$ injected
- **10** Inspection of the wells with a film camera
- **05+09-11** Geophysical repeat measurements




*Using baseline and repeat measurements, geophysical methods provide a clear signature of the $CO_2$ migration in the storage formation. Repeated seismic measurements in Ketzin show the changes in the elastic properties of the reservoir due to the carbon dioxide injection. After 15 months of operation (October 2009, approximately 22,000 tons $CO_2$ injected) the $CO_2$ could be imaged 150 to 200 m (figure: $CO_2$ signature) around the injection well.*

## Injection - Monitoring - Modelling

At the Ketzin pilot site, $CO_2$ of very high purity has been injected via the injection well into the underground storage formation since June 2008; as of December 2011, the total injected amount of $CO_2$ is about 57,000 tons. Mainly food-grade $CO_2$ (purity of › 99.9 %) is used, with the exception of an experiment in spring 2011, in which 1,500 tons of $CO_2$ from the Schwarze Pumpe pilot plant (purity of › 99.7 %) were injected. This $CO_2$ had been captured from the flue gas of a power plant. Performing this experiment is an important step for the realisation of the whole CCS concept, including capture, transport and storage.

The scientific program for the $CO_2$ storage at Ketzin involves both permanent and periodic measurements:

- permanent monitoring of the temperature and the pressure in the wells,
- geophysical and geochemical investigations in the wells,
- study of the subsurface distribution of $CO_2$ by surface-based seismic and geoelectric methods,
- measurements of the natural $CO_2$ flux (soil respiration) at the surface,
- analysis of rock samples, gases and fluids from the subsurface.

The monitoring methods used at Ketzin are among the most comprehensive in the field of $CO_2$ storage worldwide. The monitoring program is complemented by numerical simulations. With their help,

- the subsurface distribution of the $CO_2$ can be estimated and predicted,
- the processes in the storage reservoir and the cap rocks can be studied,
- and the integrity of the reservoir can be assessed.

### 2010

| | |
|---|---|
| 02 | 30,000 t $CO_2$ injected |
| 03 | Installation of manometer and riser tubing for gas monitoring |
| 04-05 | Krypton tracer test |
| 09 | Start of $CO_2$MAN project |
| 10 | 40,000 t $CO_2$ injected |

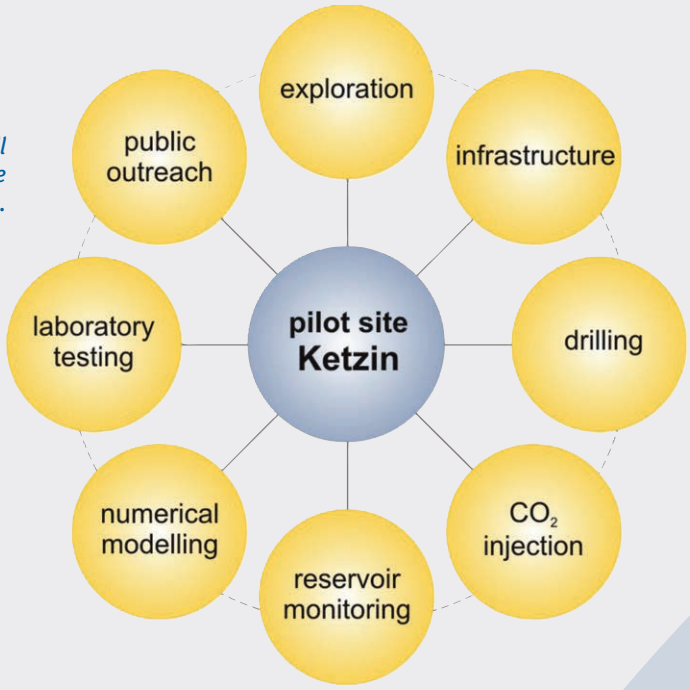
### 2011

| | |
|---|---|
| 03 | Logging campaign, inspection of the wells with a film camera |
| 04-05 | Reconstruction of the visitor centre |
| 05-06 | Injection of $CO_2$ from „Schwarze Pumpe“ |
| 06 | 50,000 t $CO_2$ injected |
| 06-08 | Drilling of observation well P300 |

### Future

- Continuation of research and development
- Continuation of $CO_2$ injection and monitoring
- Drilling of observation well Ktzi 203

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




## Results

The scientific investigations made at the Ketzin pilot site so far, have been a success. Fundamental knowledge about the geological storage of $CO_2$ in deep saline rock formations have been obtained. These results show that:

- the geological storage of $CO_2$ at the pilot site Ketzin runs smoothly and safely, and without any risk to people or the environment,
- a combination of geochemical and geophysical monitoring methods, when reasonably applied, is capable of detecting very small quantities of $CO_2$, and can be used to produce an image of the spatial distribution of $CO_2$ underground,
- interactions between fluid and rocks, induced by the injected $CO_2$, have no essential consequences at the Ketzin pilot site, and have no impact on the integrity of the reservoir and the cap rocks,
- computational simulations are capable of describing the temporal and spatial distribution of the $CO_2$, and are therefore suitable tools to predict the long-term behaviour of the storage reservoir.

## The Ketzin pilot site is under development

**Further wells are drilled.**
How can the integrity of the storage reservoir be investigated in more detail? How do rocks that have been in contact with $CO_2$ over a longer period really look like? To answer these questions, the 446 m-deep well P300 was drilled in summer 2011 and was equipped with pressure sensors and a sampling system.
In 2012, the drilling of an additional 800 m-deep well (Ktzi 203) will allow for the sampling of cores of the storage reservoir and the cap rock, and thus help to evaluate laboratory experiments by comparison with the real reservoir.

**The information centre at the Ketzin pilot site** was enlarged in 2011. Public outreach is a central part of the ongoing project work. The information centre at the Ketzin pilot site is the most important contact point. Since May 2011, a new presentation room provides an opportunity for visitors to learn about $CO_2$ storage and the monitoring methods, with on-site explanations of the latest research results. Registration is possible here:
*co2ketzin@gfz-potsdam.de*

Further information:
*http://www.co2ketzin.de*

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