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Scientific Technical Report STR12/06 - Data

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## 1. Introduction

The pilot site Ketzin is the longest-operating European onshore $CO_2$ storage site and the only one in operation in Germany. Since the beginning of the storage activity at the end of June 2008, more than 56.000 tonnes of $CO_2$ were successfully injected until December 2011.

$CO_2$ is injected into a saline aquifer. It consists of 630 m to 650 m deep sandstone units of the Stuttgart Formation of Upper Triassic age. They were deposited in a fluvial environment (Förster et al., 2010). A sequence of about 165 m of overlaying mudstones and anhydrites is sealing the storage complex and act as a caprock (Martens et al., 2012).

The research and development programme at Ketzin is among the most extensive worldwide in the context of geological $CO_2$ storage (Giese et al., 2009). Research activities have produced a broad data base and knowledge concerning the storage complex at Ketzin as well as generic cognition (Martens et al., 2012; Martens et al., 2011; Würdemann et al., 2010; Schilling et al., 2009).

This publication compiles and reviews the operational data recorded at the Ketzin pilot site. Anyone should feel free to make use of the published data for any ethical purpose (civil use) – for example for process modelling and engineering.

Datasets start with the year 2008 and will presumably be added on a yearly basis until the end of the infrastructure lifecycle.

Recommended citation for this publication is:

Möller, Fabian; Liebscher, Axel ; Martens, Sonja ; Schmidt-Hattenberger, Cornelia; Kühn, Michael (2012): Yearly operational datasets of the $CO_2$ storage pilot site Ketzin, Germany, (Scientific Technical Report : Data ; 12/06), Potsdam.

The DOI number for this publication is: 10.2312/GFZ.b103-12066.

The DOI numbers for the supplementary dataset files are up to now:

10.5880/GFZ.b103-12066.**2008**
10.5880/GFZ.b103-12066.**2009**
10.5880/GFZ.b103-12066.**2010**
10.5880/GFZ.b103-12066.**2011**

The DOI Numbers for the supplementary dataset files will be continued likewise for the coming years as stated above.

# 2. Infrastructure

## 2.1. Wellbores

To set up the field experiment at Ketzin, three new wellbores (Table 1) were drilled in 2007 with 750 to 810 m true vertical depth (TVD). One of them serves injection and monitoring purposes whereas the other two wells are for monitoring only (Prevedel et al., 2009). The distances and layout of the wellbores are depicted in Figure 1.

Data published in this contribution refer to these wellbores as follows:

*official name:* CO2 Ktzi 200/2007 – *abbreviated as*: **Ktzi 200** (monitoring)
*official name*: CO2 Ktzi 201/2007 – *abbreviated as*: **Ktzi 201** (injection and monitoring)
*official name*: CO2 Ktzi 202/2007 – *abbreviated as*: **Ktzi 202** (monitoring)

Table 1: Technical Overview on the Wellbores Ktzi 200, Ktzi 201 & Ktzi 202

| | Ktzi 200 | Ktzi 201 | Ktzi 202 |
|---|---|---|---|
| **Diameter** | 5 ½'' | 5 ½'' with 3 ½'' injection string | 5 ½'' |
| **Depth (TVD)** | 810 m | 755 m | 750 m |
| **Filter Screens (connection to reservoir)** | 642-646 m; 647-651 m; 691-695 m; 696-700 m | 632-636 m; 637-642 m; 645-649 m; 650-654 m | 621-625 m; 626-630 m; 646-650 m; 651-655 m |
| **End of injection string packer (transition to 5 ½'')** | N/A | 560 m | N/A |

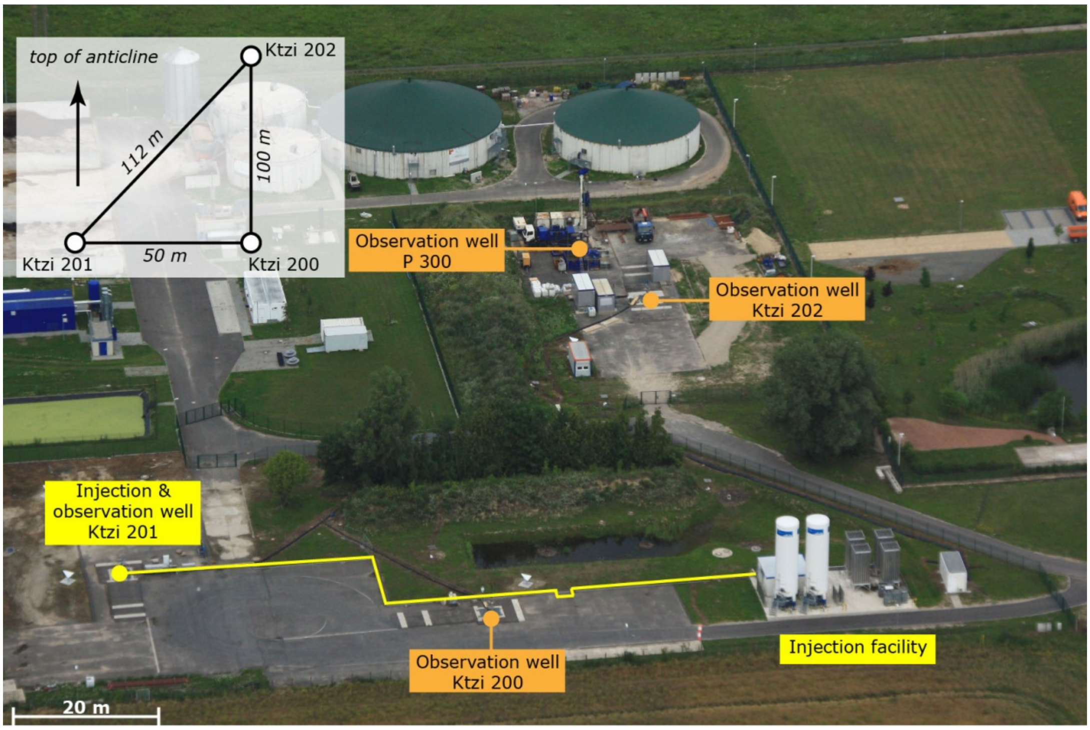


Figure 1: Aerial view on the Ketzin pilot site including the research infrastructure.

Furthermore, a shallower well (“Observation well P 300” in Figure 1) was drilled in 2011 to 446 m TVD for geochemical and pressure monitoring of the first indicator horizon above the cap rock of the storage complex. Data recorded for this well is not part of this contribution.

### 2.2. Injection facility

The injection facility at the surface consists of two intermediate storage tanks, five plunger pumps and heating devices. $CO_2$ is kept in the storage tanks at ~ -18° C and ~ 18 bar as delivered by trucks. It is then pressurised and heated to ~ 35° C and ~ 62 bar at the injection wellhead (Ktzi 201). Injection rates can be operated between 0…3,250 kg/h (setpoint value).

## 3. Data acquisition

All data published in this contribution are acquired via a Supervisory Control And Data Acquisition (SCADA) system. It consists of a programmable logic controller (PLC, supplier: WAGO) and a process visualisation / user interface / data storage („ShowIt“, supplier: Ingenieurbüro Bauer GmbH). Sensors deliver the data as a 4…20 mA signal. They are located at the site as depicted in Figure 2. The arithmetic mean value of each evaluated signal from a sensor (i.e. datapoint) is calculated over a timespan of five minutes and then stored in the SCADA with the corresponding date and time (i.e. Microsoft “Windows” operating system date and time).

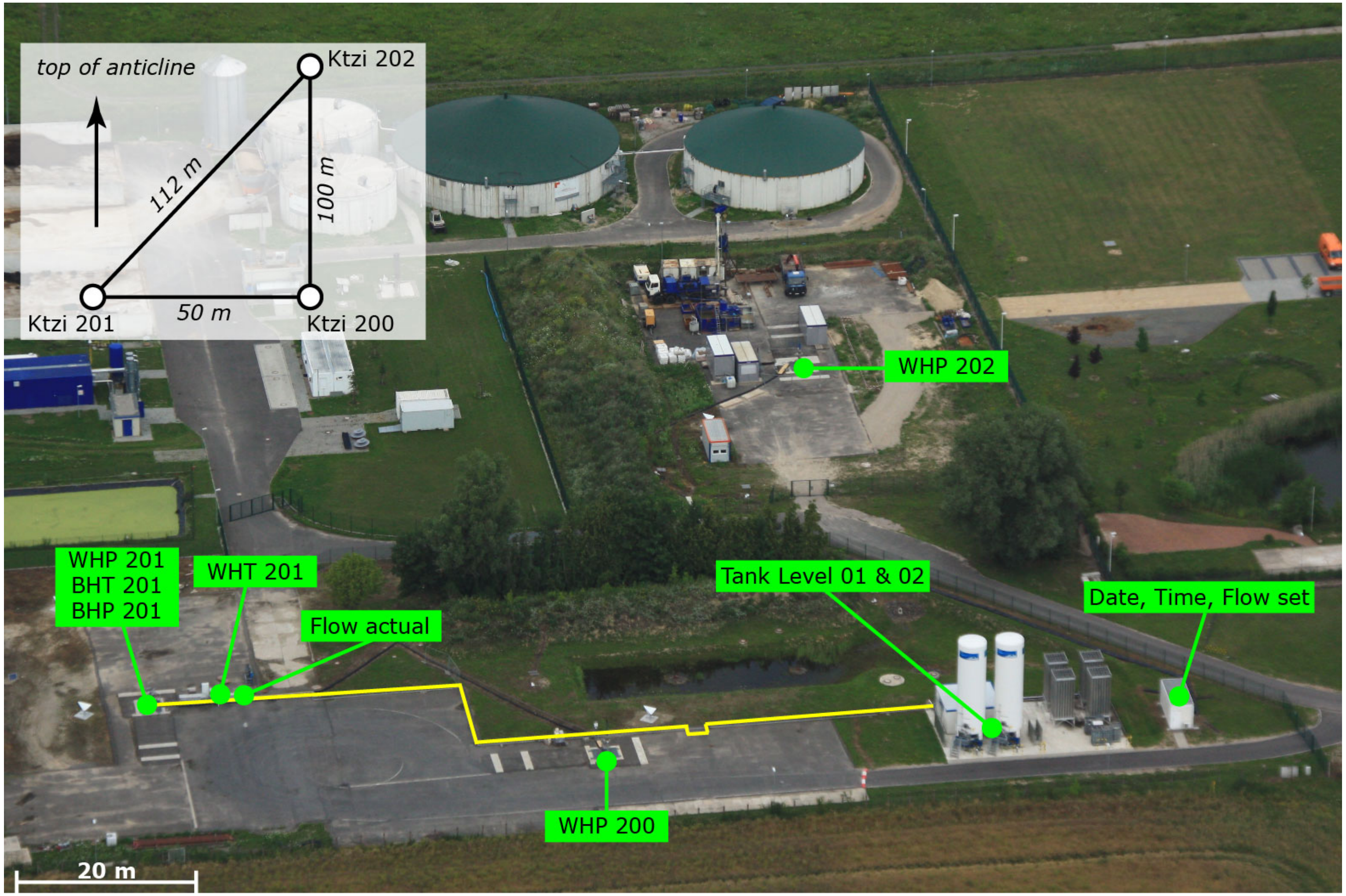


Figure 2: An overview on the infrastructure and the location of the datapoints at the Ketzin Pilot site


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## 3.1. Definitions

Datapoint in this publication means the evaluated signal from a sensor (e.g. “Flow set” with a certain value - e.g. “1.600 kg/h”)

Dataset in this publication means the entirety of all available data points at a certain date/time (e.g. all evaluated signals from the sensors at September 25$^{th}$ at 15.35 p.m.)

Yearly dataset contains all the datasets for a certain calendar year.

## 3.2. Description of the datapoints

The following datapoints are published:

### 3.2.1. Flow set [kg/h]

Set point value for the $CO_2$ mass flow through the injection facility into the injection wellbore and storage formation. Due to late implementation only available from 6$^{th}$ of August 2008.

### 3.2.2. Flow actual [kg/h]

Measured $CO_2$ mass flow. Acquired via a coriolis flowmeter (Elmess Micro Motion, 300...6,000 kg/h, accuracy +- 0.35 % of measured value; <300 kg/h with a non-specified lesser accuracy).

### 3.2.3. Tank level 01/02 [%]

Charging level of the $CO_2$ intermediate storage tanks. One tank holds up to 50 tonnes of liquefied $CO_2$ which refers to a charging level of 100 %.

### 3.2.4. WHP 200/201/202 [bar]

Wellhead pressure of the wellbore Ktzi 200/201/202, acquired via pressure gauges at (or near) the wellhead (Endress und Hauser Cerabar T PMP 131, 0...100 barg, accuracy >= 0.5 % of upper range limit)

### 3.2.5. BHP 201 [bar]

Bottom-hole pressure of the wellbore Ktzi 201, acquired via fibre-optical sensor based on Bragg grating technique (Weatherford “Optical Pressure-Temperature Gauge”, 0...690 barg (calibrated with 14,7 PSI as atmospheric pressure) at 550 m depth (~ 80 m above reservoir depth).

### 3.2.6. WHT 201 [°C]

Wellhead temperature of the wellbore Ktzi 201, acquired via a temperature gauge (Te-matec WT7490-1161 / PT 100, -40 °C ... 250 °C, accuracy Class B according to DIN EN 60751)

### 3.2.7. BHT 201 [bar]

Bottom-hole temperature of the wellbore Ktzi 201, acquired via fibre-optical sensor based on Bragg grating technique (Weatherford “Optical Pressure-Temperature Gauge”, 25 °C ... 150 °C +/- 0.1 °C.) at 550 m depth (~ 80 m above reservoir depth).

# 4. Issues observed within the datasets

The datasets contain values which are counterintuitive or, without further knowledge, simply may be seen as “wrong” or at least inconsistent. This shall be discussed here before the necessary data processing is being explained below.

## 4.1. Flow actual <> Flow set

The actual flow rate of the injection facility depends e.g. on the filling level and pressure within the storage tanks, the functioning of the heating devices, conditions in the surface and down-hole flow line. As a result, the flow rate normally oscillates around a given set-point value.

## 4.2. Flow actual > 0 while Flow set = 0

There are about 150 m of surface pipeline between the injection facility and the injection wellbore Ktzi 201. During shut-in phases where the flow is set to zero, flow may be encountered within this surface piping from one end to the other while no injection actually is taking place.

## 4.3. Flow actual is “significantly lower” than Flow set

Even in shut-in phases, the set point value for the throughput may still be above zero when the facilities have not been shut down via the SCADA for example. In these cases one can identify a shut-in phase when the Flow actual is around zero or even around a few hundreds of kg/h (flow within the piping – see above) while tank levels are not decreasing.

## 4.4. Flow actual being absolutely constant

When the injection facility has not been shut down via the SCADA, the flowmeter may “hang” and deliver a constant value for the data acquisition unit. In these cases the flow is then actually zero.

## 4.5. All values zero

Error within the data acquisition system.

## 4.6. Tank levels

The tanks are being re-filled on a constant basis. Even in shut-in times $CO_2$ may have been delivered, this explains rising fill levels under “injection stop” conditions.

## 4.7. Expected range of measured values

Since not all shortcomings in the dataset can be sufficiently explained, an overview of the range for measured values within “normal operation” of the injection facility is given in Table 2. This shall help identifying invalid data.

Table 2: Expected range of values during the injection operation

| Data Point(s) | lower range limit | upper range limit |
|---|---|---|
| **Flow set** | 0 kg/h | 3,250 kg/h |
| **Flow actual** | should fit with “Flow set” | should fit with “Flow set” |
| **Tank level 01/02** | 10 % | 100 % |
| **WHP(s)** | 0 bar | 66 bar |
| **WHT 201** | ambient Temperature | 60 °C |
| **BHT 201** | 30 °C | 40 °C |
| **BHP 201** | 60 bar | 80 bar |

# 5. Workflow of data processing

As in most cases when dealing with field data, some pre-processing also needs to be done on the Ketzin set before further evaluation actually makes sense. To make it most transparent, the processing steps have been applied within separate Excel worksheets.

The workflow is divided into three steps, which are depicted in Figure 3 as a quick reference. In the following paragraphs, the reader will find more detailed explanations.

The recommended database for further interpretation is step 03. It is marked as "final" in the spread sheets but due to the nature of large datasets from a complex field experiment, corrections may not be comprehensive and data may never just looked at "as is".

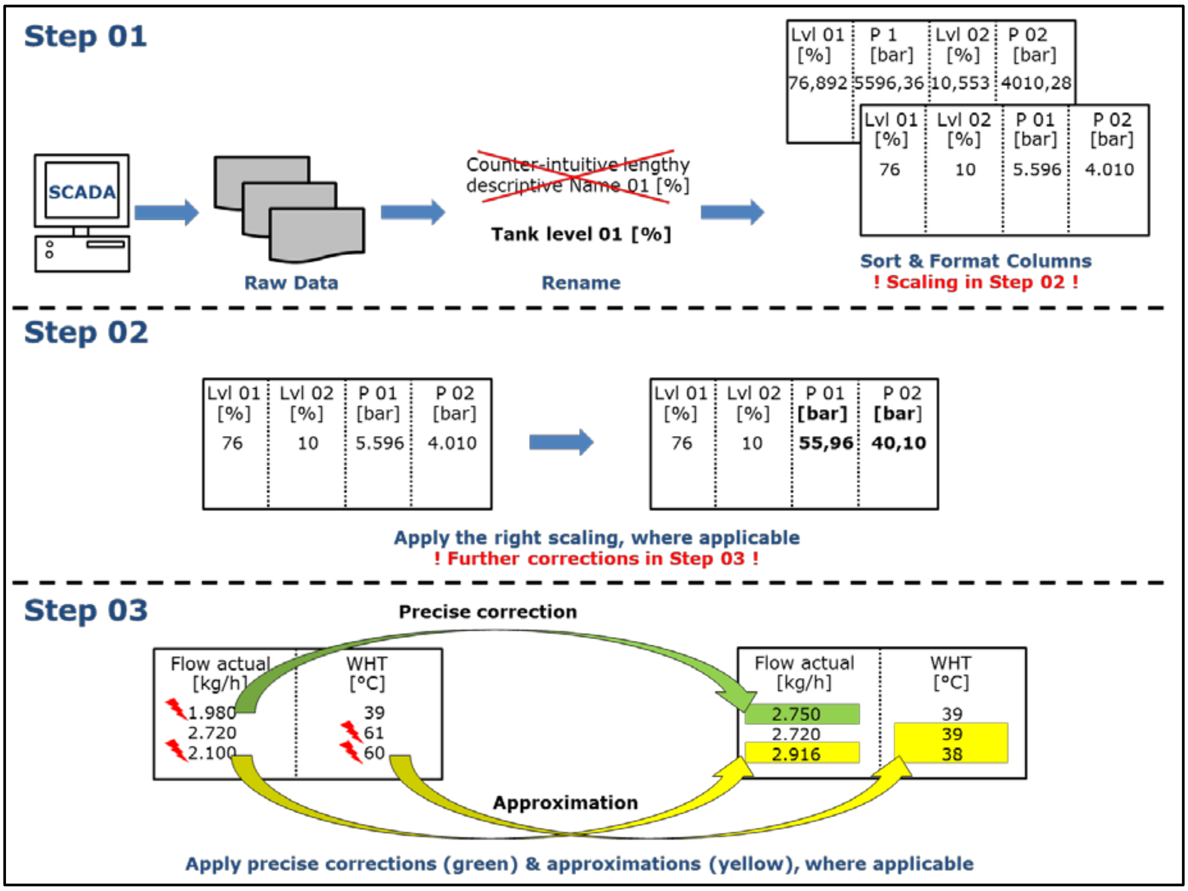


Figure 3: Quick view on the data processing from the raw field data to refined datasets

## 5.1. Step 01 (pages "[YEAR] unscaled" in the Excel data files)

Data from the SCADA has been read as comma separated values.

To make the data more readable, the original lengthy SCADA names have been changed to more meaningful short names.

The original order of the data columns has been changed in a more logical order to increase readability.

Expect for Date and Time, the display format has been changed to [#.#] (separation in sets of thousands with a dot and no decimals) to increase readability.

Note that raw data values may not fit to the dimension units given in the top row – this has been corrected in step 02 (see below)!

## 5.2. Step 02 (pages "[YEAR] scaled" in the Excel data files)

The raw data may have a wrong scaling due to programming or other issues. Thus, the correct scaling has been applied. This mostly applies to pressure and temperature data (factor 1/100). Scaled values haven been marked yellow to indicate the changes.

## 5.3. Step 03 (pages "[YEAR] final" in the Excel data files)

Some corrections had to be applied to the actual flow rate and WHT 201 due to programming issues within the SCADA. These comprise precise corrections (flow rate, factor 5,000/3,600, marked in green) and approximations (flow rate, same factor and WHT 201, correction with "-22 °C", both marked in yellow).

Finally there were several logging campaigns and other wellbore interventions as well as other issues like broken sensor cables. These metadata have been added in a separate column to allow for data interpretation. Wellbore interventions may have included

- venting pressure off the wellbore(s)
- pressurising the wellbore(s) or wellhead(s) with nitrogen (resulting in higher WHPs due to lower density of $N_2$ compared to $CO_2$)
- taking off and/or damaging of sensor cables

Larger campaigns have been marked in the remarks column. The beginning and the ending day of the campaign have been highlighted. The mark comprises always the full day although the actual wellbore intervention starts later than 0.00 a.m. and normally ends before 0.00 p.m.

It is recommended to work with this step 03 (final) datasets for further interpretation while being aware that the inconsistencies and other shortcomings mentioned earlier do still apply.

# 6. Acknowledgements

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