Activity report about field measurements in the pilot area Vogtland

Deliverable D.T3.2.2 Updated database of existing and additionally measured data at the pilot areas

Template

01 2019

H.K. ZSCHOKE & THE GEOPLASMA-CE TEAM.

[1] **Affiliation**

Contact details of author: zschoke@geoenergie-konzept.de

The involved GeoPLASMA-CE team

PP03	H. Konstanze Zschoke

Content

1. Executive summary in English language

This report describes a summary of the fieldwork activities performed in the pilot area Vogtland of the Interreg CENTRAL EUROPE project GeoPLASMA-CE. The aim of these activities was the compilation of data sets to calibrate and verify the temperature distribution and depth of the seasonal zone of the geological 3D model and potential maps created within the project.

The pilot area was explored from a petrophysical point of view – measurements of temperature and thermal conductivity. The goal of the work was to fill data gaps and create the missing potential map in the pilot area.

During a time of 19 month, temperature profiles and the effective thermal conductivity of selected borehole heat exchangers have been measured.

The data of all the newly acquired measurements were stored in a database of new measurements (D.T3.1.2), which is freely available for further use and can be downloaded from the GeoPLASMA-CE portal at: https://portal.geoplasma-ce.eu/.

2. Kurzfassung

Der vorliegende Bericht fasst alle Feldmessungen zusammen, die im Rahmen des Interreg CENTRAL EUROPE Projektes GeoPLASMA-CE in der Pilotregion Vogtland durchgeführt wurden. Ziel dieser Messungen war die Erhebung von Datenreihen, um die Temperaturverteilung und die Tiefe der saisonalen Zone im geologischen 3D-Modell sowie die Potentialkarten, die während des Projektes erstellt wurden, zu überprüfen und anzupassen.

In der Pilotregion wurden vor allem petrophysikalische Messungen durchgeführt, wie z. B. in-situ-Messungen der Temperatur und Wärmeleitfähigkeit. Ziel der Arbeiten war es Datenlücken zu füllen und das noch fehlende Kartenblatt Vogtland der Potentialkarte von Sachsen zu erstellen.

Während einer Zeit von 19 Monaten wurden dafür an ausgewählten Erdwärmesonden Temperaturprofile und Thermal Response Tests zur Bestimmung der effektiven Wärmeleitfähigkeit durchgeführt.

Die neu erhobenen Daten aller Messungen sind in der GeoPLASMA-CE Datenbank (D.T3.1.2), welche kostenfrei erhältlich ist, zu finden. Diese kann vom GeoPLASMA-CE Webportal heruntergeladen werden: https://portal.geoplasma-ce.eu/.

3. Introduction

3.1. Aim and scope of this report

This report describes the field measurements performed in the pilot area Vogtland, which have been performed within the frame of Activity A.T2.3.2. It aims at a full documentation of the assessed field data, which will be published at the GeoPLASMA-CE web portal (www.geoplasma-ce.eu).

This report contains:

- An overview of parameters measured in the pilot areas for creating the aimed project outputs
- A brief description of the methods applied for measurement and data processing
- A documentation of the field measurements performed in the PA area.
- A short description of the results achieved and how these results contribute to the generation of thematic outputs.

3.2. Overview of the chosen strategy for field measurements

In the region Vogtland, the German part of the pilot area Vogtland/ W-Bohemia, the focus of the additional field measurements has been on thermal conductivity and the undisturbed underground temperature. For this purpose, Thermal Response Tests (TRT) have been performed (see D.T3.5.1 for more details) to measure the effective thermal conductivity and temperature profile measurements have been done to derive the undisturbed underground temperature in the area.

All measurements have been performed at new built borehole heat exchangers of single-family houses. These construction sites have been chosen to avoid any economical conflicts and influence on the market since normally TRT measurements are not performed at small shallow geothermal installations.

The measured and derived datasets will be taken as reference and calibration locations of the geological 3D model which has been built for the whole pilot area. and potential maps

4. Documentation of field measurements

4.1. Temperature measurements

Measurements of the pre-test temperature profile at the BHE have been performed right in advance of the TRT measurement based on a logging device (temperature logger). The sampling interval of the data logger was 1 second.

There have been two sites where no TRT was performed but still a temperature profile could be realized.

The estimation of the undisturbed average BHE fluid temperature via non-heating circulation tests of the TRT device does not fulfil the standards at GeoPLASMA-CE to reach a maximum error of 5%.

For the temperature measurements a diver with temperature and pressure sensors has been used. It was attached to a cable and was inserted slowly into the boreholes until it hit ground (see figure 1). It measured temperature as well as the hydrostatic pressure, which is used for depth calculation, in one second intervals. The specifications of the device are shown in the following table.

	Range	Accuracy	Resolution
Pressure unit	100 m	±10,0 cmH_2O	2,0 cmH_2O
Temperature unit	-20 ... +80 °C	±0,1 °C	0,01 °C

Figure 1: measurement of temperature profile

In the following table all temperature measurements and the date of the measurements have been listed. The data and more information are available in the GeoPLASMA-CE data base.

Bad Brambach	27.04.2017
Adorf	13.04.2017
Treuen	15.09.2017
Plauen	18.09.2017
Markneukirchen	24.10.2017
Plauen	11.12.2017
Plauen	19.04.2018
Auerbach	27.04.2018

Tirschendorf	10.09.2018
Plauen	19.09.2018
Werda	02.10.2018
Adorf	07.12.2017
Reichenbach	27.04.2018

4.2. Thermal Response Test

Thermal Response Tests (TRTs) are a good method to determine the effective thermal properties of the borehole heat exchanger and the rocks. The test evaluation can be done with analytical methods and yields to the effective thermal conductivity and the heat transfer resistance from the fluid to the rocks of the BHE. The effective conductivity includes a conductive, a convective and an advective term. The latter two are caused by water flow and should be comparable small to the conductive term:

$$\lambda_{effective} = \lambda_{conductive} + \lambda_{convective} + \lambda_{advective} \quad [1]$$

where $$\lambda_{convective} + \lambda_{advective} \ll \lambda_{conductive}$$

After drilling the borehole to the designed depth, the pipes are brought in. Then the borehole is grouted from the bottom to the top and the pipes can be filled with the heat carrier fluid (e.g. water). Then the pressure test of the pipes can be done. Before the TRT measurement can start, a waiting time of 3 days (for rock conductivities > 1.7 W/m/K) to 5 days (for rock conductivities < 1.7 W/m/K) is recommended. Then the undisturbed ground temperature can be determined, usually made by temperature logging in the borehole (see chapter 4.1) or by evaluating the fluid temperature of the circulating fluid with a switched off heating/cooling device and a small sampling interval.

The response test facility is placed as close as possible to the BHE and hydraulically connected to the borehole pipes. The test loop (i.e. the collector pipes and the response test device) is filled with water, purged and fully vented. All exposed parts between the borehole and the response test device must be thermally insulated to minimize the influence of the ambient temperature. After that a heat carrier fluid (most suitable is water) circulates through the U-pipe in the borehole. After a while a constant level is reached, which represents the average undisturbed temperature of the system.

Hereafter, a constant fluid flow rate is set, and the heating/cooling device is switched on. This is the beginning of the TRT. Mind, that the injected heating/cooling power and the flow rate have to be constant during the whole test. If a double U-pipe is used check, that the load distribution is equal for both pipes. Important is to record the temperature of the fluid directly at the in- and outlet of the BHE and the flow rate of the fluid of each pipe. Additionally, the ambient temperature and the heating power can be of interest for error detection. The sample interval of the logging device was set to 30 seconds. The temperature of the fluid develops in form of a logarithmic function over the time, hence the temperature rise gets smaller. The test proceeds until the conductive heat transport dominates and steady-state conditions are obtained, for at least 48 h. For the tests in the pilot area Vogtland the measurements have been performed minimum 60 hours. After that, the heating/cooling device can be switched off and the regular TRT measurement is completed. Additionally, the temperature decline can also be measured, hence the circulation pump is left on for another number of hours until the borehole temperature is back near the initial conditions.

After the TRT measurement the following information are needed additionally for test evaluation:

- length and radius of the bore hole (see drilling documentation)
- type and layout of the BHE, amount, diameter and thickness of the pipes (see drilling documentation)
- heat capacity and density of the heat carrier fluid (temperature dependent), especially if antifreeze fluid is involved

Within the pilot area Vogtland eleven Thermal Response Tests have been performed between April 2017 and October 2018. In the following table shows where and when measurements have been performed.

	from	to
Bad Brambach	27.04.2017	02.05.2017
Adorf	13.04.2017	18.04.2017
Treuen	15.09.2017	18.09.2017
Plauen	18.09.2017	21.09.2017
Markneukirchen	24.10.2017	27.10.2017
Plauen	11.12.2017	15.12.2017
Plauen	19.04.2018	22.04.2018
Auerbach	27.04.2018	30.04.2018
Tirschendorf	10.09.2018	13.09.2018
Plauen	19.09.2018	22.09.2018
Werda	02.10.2018	05.10.2018

The assessment sheet for the documentation of the measurements can be found in D.T3.5.1 Joint report on chosen approaches and methods for calibration.

Following one can find some impressions of the measurements:

Figure 2: Thermal Response Test device

5. Data processing

The Thermal Response Test evaluation has been done by the analytical line source approximation method. This simple method can be applied as long as the heat transfer in the BHE is dominated by thermal conduction. At more complicated situation or if a detailed thermal conductivity profile of the drilled section is needed, methods based on numerical modelling or inverse approximation of subsurface models can be applied.

The analytical line source method leads to the following output parameters:

- Effective thermal conductivity, averaged for the investigated section of the BHE tubing.
- Thermal resistance of the borehole based on an estimation of the volumetric heat capacity of the thermally activated subsurface volume around the BHE.

The VDI guideline presents the straightforward estimation of the average effective thermal conductivity and the thermal resistance of the borehole based on the line source approach.

The effective thermal conductivity is corresponding to the slope (k) of the linear approximation of the measured fluid temperature T_f (average of T_{inlet} and T_{outlet} at the time t) against the logarithm of time during the test (ln(t)):

$$\lambda = \frac{\dot{q}}{4\pi k} \qquad [2]$$

Where: $\dot{q}$… average specific heat transfer rate in the BHE (W/m), realized during the test and λ… effective thermal conductivity (W/m/K).

More information on the processing of TRT data can be found in deliverable D.T3.5.1.

5.1. Transfer of field data to the joint databases

In a last step, the processed field data have been summarized and documented for a transferring them to the following databases:

- Metadata database of relevant input data (D.T3.1.2) for a full documentation of the achieved datasets.
- Key value database for publishing the achieved results (D.T3.2.1).

The metadata description of the produced datasets follows the joint concept on geodata management, which is described in Deliverable D.T2.3.1.

The summarized of datasets, shown in the key value database are characterized by:

- Number of individual measurements (≥1)
- Presentation of either alpha-numeric (e.g. <0,01 mg/l) or numeric values
- The dataset is characterized by a single or mean-, minimum- and maximum value as well as by the standard deviation (in case of at least 3 single datum points).
- All presented values are allocated to a measurements period, a surface location and a depth interval of the measurements.

6. Summary and conlusions

In the pilot area Vogtland a total number of 23 individual measurements have been performed. This relatively low number of data is resulting from the type of measurement and the availability of BHE which could be tested. The former, the TRT measurements, are very time consuming. To get one average value of a tested BHE four days of testing, including mounting and demounting of the test, are necessary. Second, since our aim was to perform a TRT only on BHE installations of single-family houses the measurements were very dependent on the will and cooperation of the owners as well as the drilling companies. The latter did not want to wait one week between drilling and connecting the BHE to the heat pump most of the time.