Journal of Geography and Geology; Vol. 6, No. 3; 2014
ISSN 1916-9779 E-ISSN 1916-9787
Published by Canadian Center of Science and Education

Performance of the Subsurface Hydraulics in a Doublet System Using the ThermoGIS Calculator

A. M. Al-Mukhtar[1,2]

[1] Technische Universität Bergakademie Freiberg, Faculty of Geosciences, Geoengineering and Mining, Institute for Geology, Gustav-Zeuner-Straße 12, Freiberg, Germany

[2] Al-Khwarizmi College of Engineering, University of Baghdad, Baghdad, Iraq

Correspondence: A. M. Al-Mukhtar, Technische Universität Bergakademie Freiberg, Faculty of Geosciences, Geoengineering and Mining, Institute for Geology, Gustav-Zeuner-Straße 12, 09599 Freiberg, Germany. E-mail: almukhtar@uni.de

Received: May 2, 2014 Accepted: June 10, 2014 Online Published: July 8, 2014

doi:10.5539/jgg.v6n3p90 URL: http://dx.doi.org/10.5539/jgg.v6n3p90

Abstract

The doublet system that consisting of injection and production wells is utilized for heat extracting from the aquifer. This work presents the doublet calculator using the ThermoGIS analysis. It is an analytical calculator software for subsurface flows. It contains a large variety of potential aquifer maps. The geothermal aquifer groups were determined. The relevant data were imported from the geological maps. Recently, the compiled geothermal location maps are collected in one framework. An example map and location have been used to show some parameters for geothermal extraction. The uncertainties of the hydro-geological properties could be also considered in term of standard deviations. ThermoGIS software has the abilities to describe the aquifer performance. The users can change the required data according to their measurements and desired performance. By using hydro-geotechnical and drilling parameters, the performance can be determined accordingly.

Keywords: aquifer performance, doublet calculator, geothermal energy, heat distribution, ThermoGIS

1. Introduction

The geothermal energy production is increasing for electricity generation and heating purpose. The geothermal exploration and production is generally carried out at depths around 2-5 km, which is called a deep geothermal energy system (Kramers, Kronimus, & Mijnlieff, 2010; Britain, 1978; Kramers, Van Wees, Pluymaekers, Kronimus, & Boxem, 2012; Van Wees, Kramers, Juez-larré, Kronimus, & Mijnlieff, 2010). This tool will demonstrate the technical and financial aspects of such system. The management of geothermal response is based on the evaluation process (Singhal & Gupta, 1999). Therefore, the web based calculator ThermoGIS is presented in this work (TNO ThermoGIS, 2013). The doublet system, i.e., two wells is utilized for heat extracting using a pumping well and an extracting well. Hence, the temperature is extracted from a deep hot dry rock (HDR). The water has been cooled after the heat extracting and its returned into the same aquifer horizon (Holzbecher, Oberdorfer, & Maier, 2011). Different injection projects have developed in Europe at different drilling depths, see (Evans, Zappone, Kraft, Deichmann, & Moia, 2011).

For the numerical computation, the doublet calculator collects all the relevant data from the geological maps that are integrated within ThermoGIS™ software (Van Wees, Kramers, Juez-larré, Kronimus, & Mijnlieff, 2010). Nevertheless, a framework of collecting maps in a worldwide can be shown. It is a public web-based information system that provides depth, thickness, porosity and permeability maps of many potential aquifers. We think that the adopted maps can be compared with worldwide potential geothermal locations (see Figure 1). Hence, a closer approach may be proposed.

It enables the user to automatically assess the generated power, expected flow rate, the Coefficient of Performance (COP), economic variables and different standard deviated properties (Kramers, Kronimus, & Mijnlieff, 2010; Pluymaekers & Mijnlieff, 2010). The software downloads data from the TNO site (TNO ThermoGIS, 2013), for any specific location. A number of aquifers groups have been presented, e.g. KN, TR, and RO. Some of these groups (TR, RO) have the stacked maps that were generated from a vertical accumulation of aquifers. These aquifers tend to give a better performance if these are perforated (Kramers, Kronimus, & Mijnlieff, 2010). An overview group and aquifer are also existed which have been selected in advance to show the proposed heat area.

The probability maps (P90, P50, and P10) are available also for some aquifer maps and their properties due to the uncertainties at different depths (Van Wees, Kramers, Juez-larré, Kronimus, & Mijnlieff, 2010). This work presents an overview of the ThermoGIS simulation, advantages and disadvantages. A brief description of thermal properties is also presented. By using new geotechnical data (such as permeability, porosity, depth, thickness, temperature and transmissivity) and well properties, the performance can be determined accordingly.

1.1 Heat of the Subsurface

Heat in place (HIP) is the maximum theoretical extractable heat in the aquifer (Kramers, Kronimus, & Mijnlieff, 2010; Britain, 1978). It's called also the heat capacity of the reservoir in GJ/m^2. It is the product of the weighted volumetric heat capacity of rock and pore fluid times the volume of the rock times the temperature difference of reservoir and average surface temperature (Kramers, Kronimus, & Mijnlieff, 2010). Therefore, it has been considered as the key parameters for the aquifer selection (Salimi, Groenenberg, & Wolf, 2011). The potential recoverable heat (PRH) can be recovered from the reservoir, unconstrained by techno-economic limitations, irrespective of flow properties. Taking into account these effects it is assumed that the recoverable heat is about 33% of the HIP depending on the local reservoir conditions (Kramers, Kronimus, & Mijnlieff, 2010; Pluymaekers & Mijnlieff, 2010).

Further to the PRH is calculated replacing surface temperature with injection temperature for a specific application, and putting an associated lower limit for producing temperature. Consequently, compared to HIP, less heat can be recovered and particular areas will not be available for heat production, depending on the minimum required production temperature. Therefore, the volume of rock in PRH is a subset of HIP. For greenhouse applications, the minimum production temperature is assumed to be 45 °C and the temperature of re-injection 25 °C. For the spatial heating the production temperature is assumed 65 °C and re-injection at 40 °C (Kramers, Kronimus, & Mijnlieff, 2010). According to HIP and PRH, the geothermal energy can be calculated. Such system is used in a few places over the world. For both electricity and heating, geothermal project has been growing in recent year in northwestern Europe, where the sedimentary basins at depth from 2 to 5 km are existed (Van Wees, Kramers, Juez-larré, Kronimus, & Mijnlieff, 2010). The Netherlands still the excellent location for geothermal exploration due to the comprehensive data that allowing insight the geological parameters (Van Wees, Kramers, Juez-larré, Kronimus, & Mijnlieff, 2010; Mock, Tester, & Wright, 1997; Duchane & Swenson, 1995). Nevertheless, Germany–Horstberg location has a low transmissivity. Therefore, the sedimentary formations in the northern German basin are not considered for the extraction of geothermal energy (Systems & States, 2006).

2. Performance Assessment Procedure

The hydrogeological property maps have been calculated taking into account the temperature, thickness, permeability, depth, thickness, porosity, transmissivity, and the thickness of the reservoir (Kramers, Van Wees, Pluymaekers, Kronimus, & Boxem, 2012). Due to uncertainties, the transmissivity (KH) and pressure have been given with probabilities P10, P50, and P90. The sufficient transmissivity of the deeper aquifer are required for extraction the sufficient geothermal energy (Armstead, 1978).

The stimulation of geothermal energy is required for heating. Therefore, the investigation of the possibility of the warm water, geothermal system is needed. Using ThermoGIS, the potential geothermal area in the center and Western Europe can be estimated (Kramers, Kronimus, & Mijnlieff, 2010; Van Wees, Kramers, Juez-larré, Kronimus, & Mijnlieff, 2010). An overview of geothermal areas should be determined. At first, potential aquifer should be located in a subsurface. Then, the potential map of the warm water, geothermal energy has to be analyzed.

2.1 Determination of the Potential Map of the Geothermal Energy

After starting the ThermoGIS application, the warmer water and hotter areas or heat in place (HIP) can be found. However, the online tool has been developed to expect maximum production temperature up to 3 Km depth (Kramers, Kronimus, & Mijnlieff, 2010; Van Wees, Kramers, Juez-larré, Kronimus, & Mijnlieff, 2010). From the scene, the user can indicate that sufficient heat can be extracted from the subsurface by selecting an overview aquifer group from the scenario box (see Figure 1).

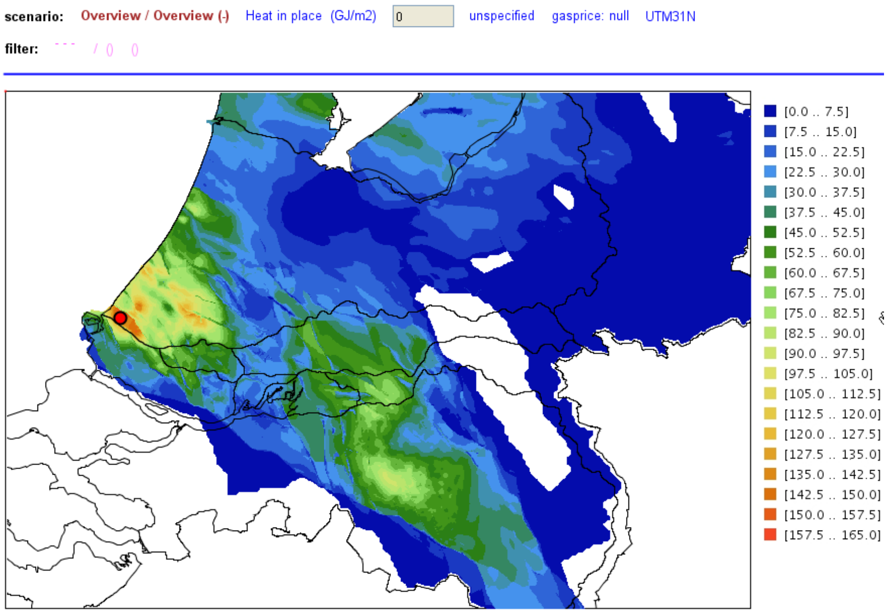


Figure 1. Heat distribution of the potential warm geothermal energy

The recoverable heat (RH) map shows the areas where the heat can be extracted with respect to the gas heating price (Kramers, Kronimus, & Mijnlieff, 2010; Pluymaekers & Mijnlieff, 2010; Van Wees, Kramers, Juez-larré, Kronimus, & Mijnlieff, 2010). The cross section view with lithostraigraphical group rock layers were shown by taking a line cross the area, see Figure 2.

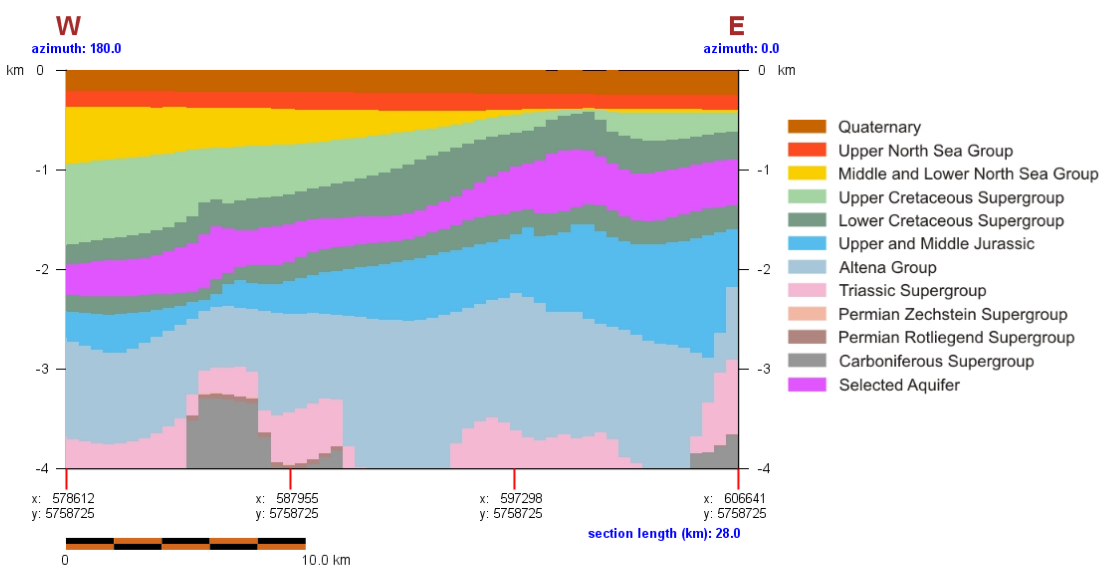


Figure 2. Cross section view

2.2 Aquifer Selection

A district area where the geothermal proposal is needed was selected according to the HIP from Figure 1. The location of the proposed area has the following coordinates: x=580704; y=5758338 where higher HIP is existed. This aquifer is suitable for geothermal extraction. The general properties of the selected area are shown on the following map (see Figure 3). It seems that the selected area has a potential warm geothermal area, HIP=155.2 GJ/m^2. In addition, it has a sufficient transmissivity in term of transport aperture and the arrangements of fracture.

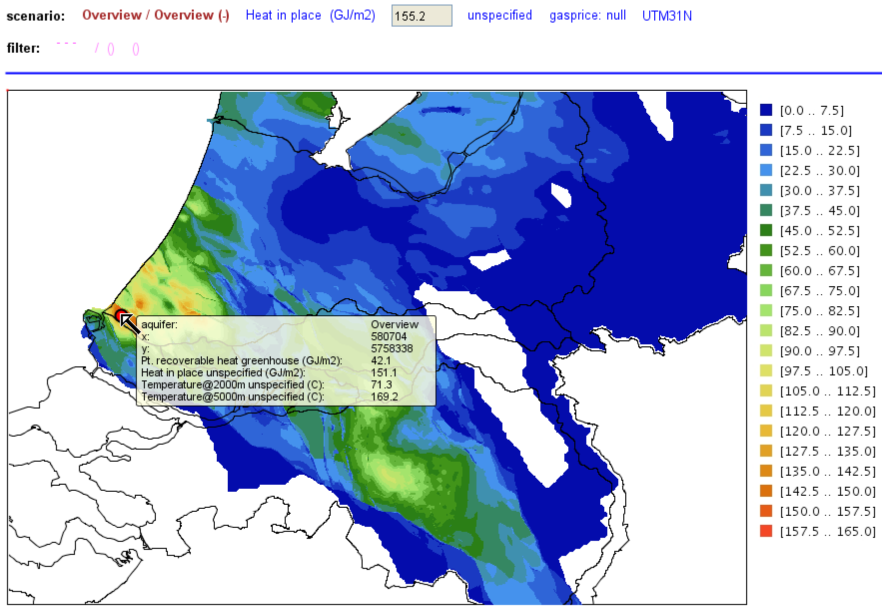


Figure 3. Information's tags on the proposed warm area

The doublet calculator is carried out by clicking the info tag when a certain aquifer group (KN) has been selected (see Figure 4). Nevertheless, different groups of aquifers such TR, and Ro are listed in addition.

It should be emphasized that each aquifer has different maps of properties. The retrieving process is required after each aquifer selection. Figure 4 shows the result after the data is retrieved for the aquifer type KN/KNWNB. Heat in place (GJ/m^2) was specified.

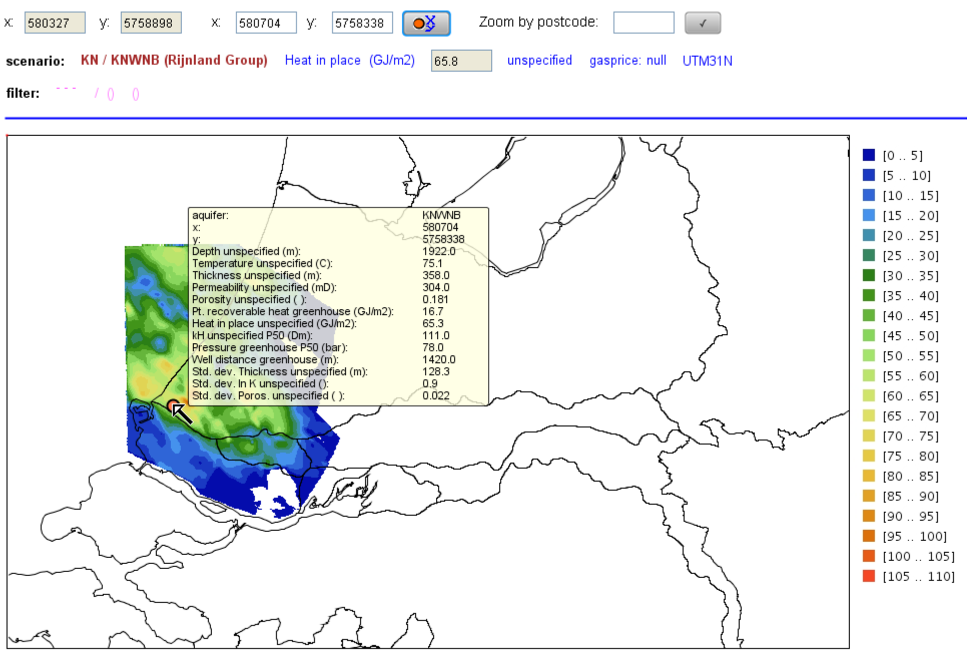


Figure 4. Heats in place, aquifer group KN, KNWNB type

2.3 Determination of the Specific Properties

The amount of geothermal power has been estimated which depends on the ground HIP. Therefore, the temperature, and permeability was selected from the scenario box because they are related to the recoverable heat (see Figure 5).

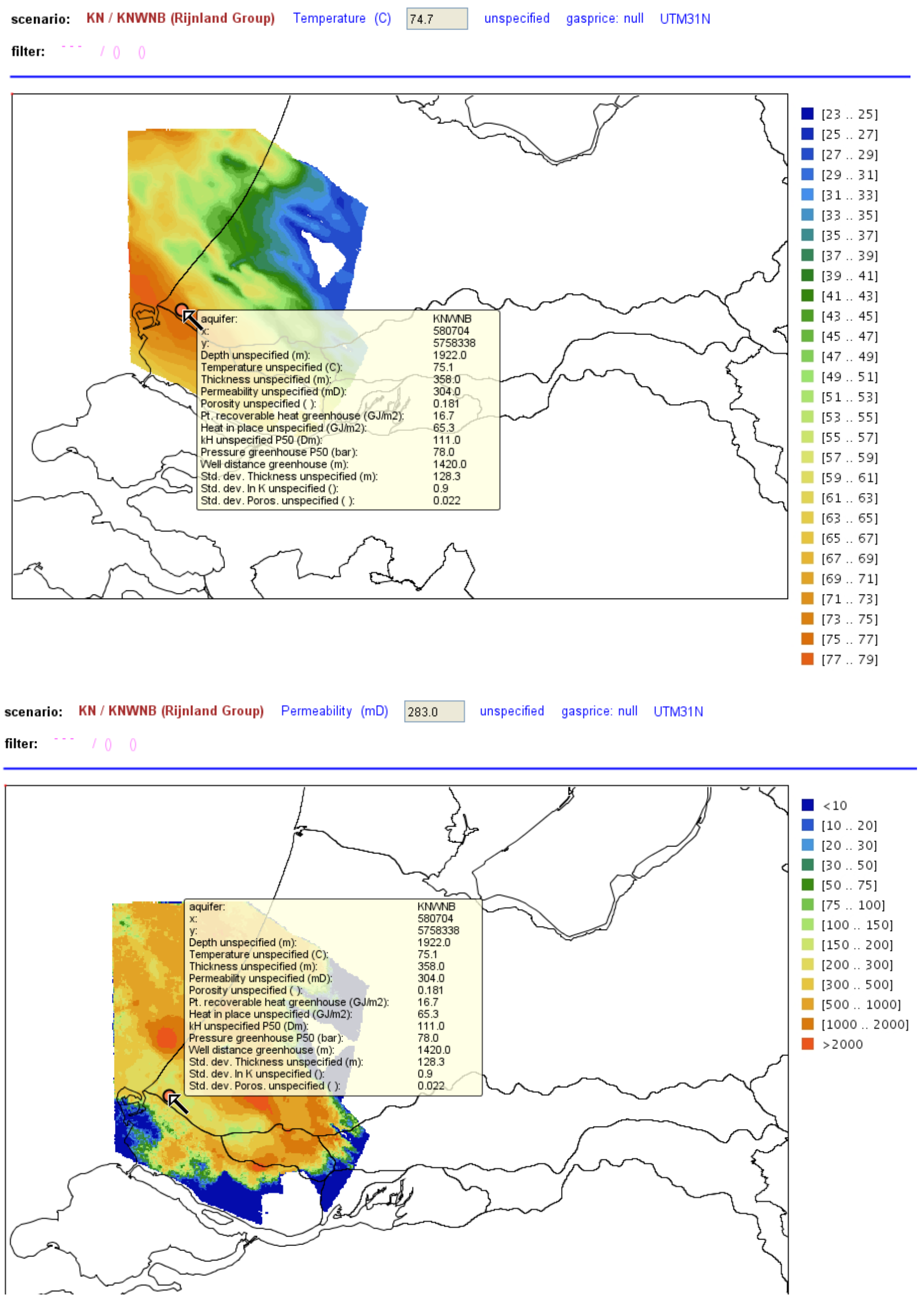


Figure 5. Temperature and permeability distribution in KN aquifer area

The numerical calculations with relevant plots are presented in the form of curves. However, the default number of runs is 500; the number of simulation runs can be increased (see Figure 6).

number of simulation runs (-) 500 Calculate ! Save Scenario greenhouse member: KNWNB x: 580704 y: 5758338

Geotechnical input

A) Aquifer properties

	min	median	max		min	median	max
aquifer permeability [P90,P50,P10] (mD)	100.0	304.0	923.0				
aquifer net to gross (-)	0.99	1.0	1.01	aquifer gross thickness (m)	61.0	358.0	655.0
aquifer top of injection (m)	1730.0	1922	2114.0	aquifer top of production (m)	1730.0	1922	2114.0
aquifer salinity (ppm)		70000					

B) Doublet and well properties

skin injection (-)	0.5	skin production (-)	2.0
well outer diameter (inch)	8.0	well distance at aquifer level (m)	1420.0
injection well deviation (m)	1350	production well deviation (m)	1500
tubing roughness (milli-inch)	1.38	tubing inner diameter (inch)	7.0
minimum doublet performance (MW)	2	desired doublet performance (MW)	10
surface temperature (°C)	10	injection temperature (°C)	25.0
geothermal gradient (°C/m)	0.031		

C) Pump properties

pump efficiency (-)	0.6	production pump depth (m)	300
maximum pump capacity (m³/h)	100	pump pressure difference (bar)	78.0

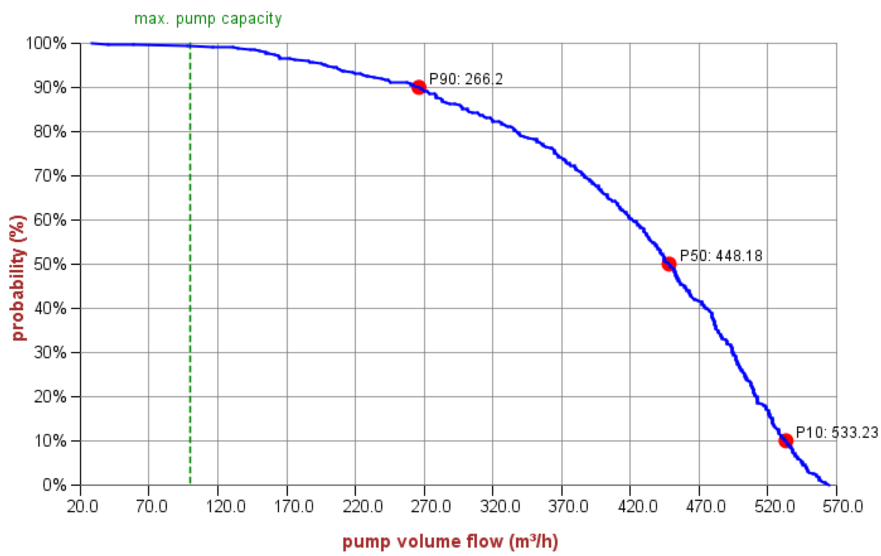
Economic input

A) Initial Input

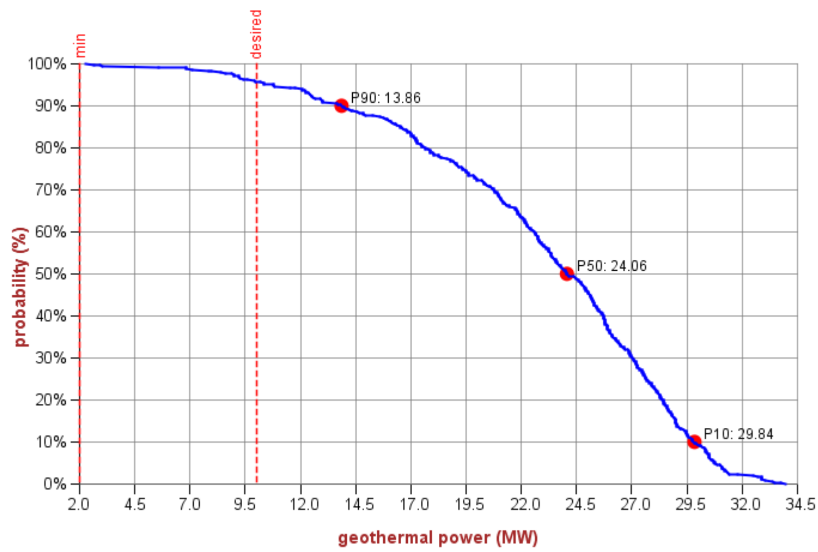
	min	median	max		min	median	max
electricity price to buy (cts/kWh)	7.9	8.0	8.1	heat price to sell (€/GJth)	5.9	6.0	6.1
uplift (yrs)		100		depreciation (yrs)		10.0	
tax rate (%)		25.5		discount rate (%)		7.0	
economic lifetime (yr)		35		MEI funding (M€)		1.5	
well cost scaling (-)		1.5		heat exchanger season factor (-)		0.6	

Figure 6. Screenshot of the default parameters, aquifer type KN/KNWNB

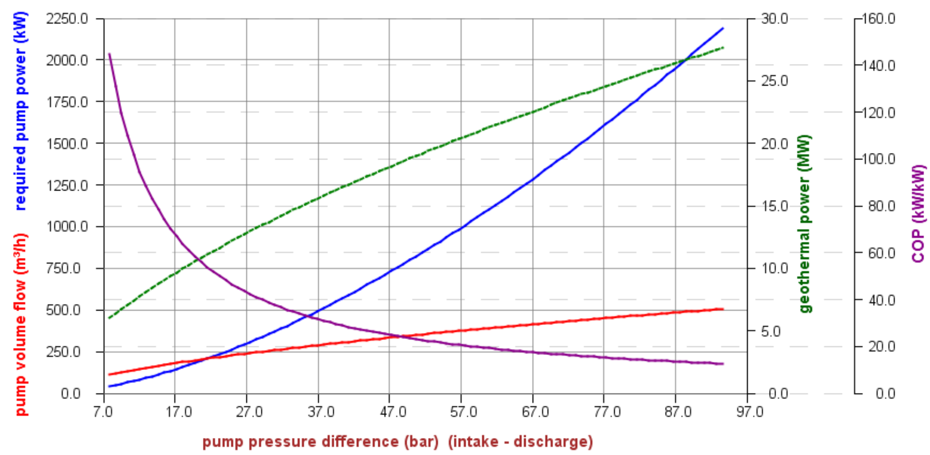
Nevertheless, these data are changeable and the proposed data according to the input and outputs designed measurements can be used. The increasing of pumping pressure will increase the amount of heat extracting. However, this may need more power consumption and undesired costs. Therefore, to enhance the geothermal system (EGS) the using of CO_2 is recommended for long-term production, see Figure 7. It is may possibly cause a fluid circulation without external pumping (Pruess, 2006). This will reduce power consumption and increasing the heat extraction.



a) Pump volume flow



b) Geothermal power



c) Pump pressure

Figure 7. Expected results from the doublet calculator

3. Conclusions

This paper aims to describe the ThermoGIS web-based simulator. It's a comprehensive tool based on the data that is collected over the past years. As based on the temperature and thermal properties, the techno-economics to compute the heat structures and performance is incorporated. The evaluation of the geothermal performance can be determined using ThermoGIS software. The technical performance of the geothermal system was discussed briefly. The program needs a retrieving process after each selection. However, the data depends on the working server; the connection error is most probably caused by the firewall restrictions of the Java Runtime of used network. Therefore, the network connection and a powerful computer processor are required to prevent any interpretation during the evaluation and retrieving of the data. The data will be imported accordingly. This tool also demonstrates the technical and financial aspects of such system. Different hydrogeological and hydrotechnical maps for aquifer depth, thickness, permeability, flow properties and temperature are incorporated within ThermoGIS. It provides a significant tool due to the large geological maps and properties that are integrated. Therefore, the graphical plots that describe the aquifer performance have been presented. The desired geothermal power has been calculated according to the aquifer performance and the key parameters such as economic calculation, permeability and temperature. Hence, the program provides a unique tool for the performance evaluation. The results can be compared within similar areas in the world. As based on these results, the enhancement of geothermal system due to the using of CO_2 can be proposed if the relevant factors are known.

Acknowledgments

I would like to express my sincere gratitude to Prof. Dr. B. J. Merkel, Vice-rector for research of TU Bergakademie Freiberg, Head of Geology Department for giving me the opportunity to carry out the research project of Hot Dry Rock and for enlightening discussions about Geothermal.

References

Armstead, H. (1978). *Geothermal Energ* (pp. 341-346).

Britain, G. (1978). The critical dependence of modern society on minerals and fuels has fostered an increasing awareness of the need to estimate not only the quantities that could be produced under present economic cond. *Methods For Regional Assessment Resources of Geothermal, 7*, 53-89.

Duchane, D. V., & Swenson, D. (1995). *Heat Mining to Extract Hot Dry Rock (HDR) and Scientific Progress* (pp. 1-8).

Evans, K. F., Zappone, A., Kraft, T., Deichmann, N., & Moia, F. (2011). A survey of the induced seismic responses to fluid injection in geothermal and CO_2 reservoirs in Europe.

Holzbecher, E., Oberdorfer, P., & Maier, F. (2011). Simulation of Deep Geothermal Heat Production. In *Proceedings, COMSOL Conference 2011.*

Kramers, L., Kronimus, R. A., & Mijnlieff, H. F. (2010). V1.0 Part 1 User Manual.

Kramers, L., Van Wees, J. D., Pluymaekers, M. P. D., Kronimus, A., & Boxem, T. (2012). Direct heat resource assessment and subsurface information systems for geothermal aquifers; the Dutch perspective. *Netherlands Journal of Geosciences, 91*(04), 637-649.

Mock, J. E., Tester, J. W., & Wright, P. M. (1997). GEOTHERMAL ENERGY FROM THE EARTH:Its Potential Impact as an Environmentally Sustainable Resource. *Annu. Rev. Energy Environ., 22*(1), 305-356. http://dx.doi.org/10.1146/annurev.energy.22.1.305

Pluymaekers, M. P. D., & Mijnlieff, H. F. (2010). Part II : Methodology.

Pruess, K. (2006). Enhanced geothermal systems (EGS) using CO_2 as working fluid—A novel approach for generating renewable energy with simultaneous sequestration of carbon. *Geothermics, 35*(4), 351-367. http://dx.doi.org/10.1016/j.geothermics.2006.08.002

Salimi, H., Groenenberg, R., & Wolf, K. (2011). Compositional Flow Simulations of Mixed CO_2-Water Injection into Geothermal Reservoirs: Geothermal Energy Combined With CO_2 Storage.

Singhal, B., & Gupta, R. (1999). *Applied hydrogeology of fractured rocks*. Kluwer Academic Publishers (now Springer).

Systems, E. G., & States, U. (2006). *The Future of Geothermal Energy The Future of Geothermal Energy*.

TNO ThermoGIS. (2013). Retrieved February 26, 2014, from http://www.thermogis.nl/thermogis_en.html

Van Wees, J., Kramers, L., Juez-larré, J., Kronimus, A., & Mijnlieff, H. (2010). ThermoGIS : An Integrated Web-Based Information System for Geothermal Exploration. No. April (pp. 25-29).