BeTemper

1. Introduction and general context

The current energy transition towards Renewable Energy Sources (RES) in Europe is mainly driven in Belgium by intermittent sources such as wind turbines and photovoltaic panels. Other sources are however available, such as biomass and geothermal resources. The latter can take various forms among which Ground Source Heat Pumps (GSHP). This Geothermal RES could represent an important supply for the heating/cooling market, which represents 48% of the energy consumption in Belgium. The main advantage of most geothermal systems is their availability without any geographical, seasonal or climactic restrictions (except legal constraints) and in principle the geothermal heating and cooling could match the entire heating and cooling demand. The interest in using the ground as a source or storage device for thermal energy has grown considerably in the last few years and the market is expected to grow significantly by 2020 (*Petitclerc, 2013*). However, research in the thermal characteristics of the soil and subsoil is lagging behind the industrial development, resulting in frequent overdimensioning of installations, hence higher costs and abandoned though promising projects.
Shallow geothermal energy systems can be divided into two main groups: 1) vertical heat exchangers are installed in drill boreholes to a depth of up to 300 m and 2) in the second group, geothermal heat collectors are inserted to a maximum depth of 10 m into a horizontal system. Only the second type is considered in the ThermoMap context to explore exclusively the very shallow geothermal potential.

✓ Ongoing intiative: ThermoMap (EU FP7-ICT project)

The Geological Survey of Belgium (GSB) is participating to the ThermoMap project (Area mapping of superficial geothermic resources by soil and groundwater data) which is an EC co-funded project (FP7-ICT Policy Support Programme) (*Bertermann et al., 2013*). The main objective of ThermoMap project focuses on the mapping of very shallow geothermal energy potentials (vSGP) in Europe (www.thermomap-project.eu). For Belgium, two test-areas around the cities of Gent and Liège were selected, as they are representative for the different geological and geographical settings. During the testing phase of the project, an additional research phase was conducted at GSB in order to evaluate the variability of ground thermal properties (thermal conductivity: λ in W/mK) in the test-areas. Thermal and textural properties of soil samples were measured at the laboratory of the Friedrich Alexander University Erlangen (FAU, Germany). The analyses show encouraging results for soft sediments, which is usually considered as a major challenge due to their extreme variability.

✓ Proposal: ThermoMap 'deep' for Belgium

In Belgium, 75% of the installed GSHP are vertical loops, the next essential step is therefore to assess the potential for a greater depth. This approach is in agreement with the recommendation of M. Burkhard Sanner (President of European Geothermal Energy Council). However no fundamental research in Belgium has been yet conducted on geological characterisation to improve the performance of these systems. There are wide possible variations with regard to the effective heat transfer between the transport medium and the rocks in the underground, which is crucial to optimise performances and reduce the costs (*Sanner, 2001, Gehlin 2002, Acuña, 2013*). Nowadays, large differences in design of vertical closed loop systems are made by different experts for a similar geological situation. This has two reasons, a lack of knowledge on the thermal characteristics and an insufficient analysis of the thermal energy need profile of the building, resulting in large uncertainties on the design. Following the experience of GSB, also based on its existing rock and borehole collections, the current proposal will focus on the subsoil aspects, while other initiatives like Smart

Geotherm conducted by CSTC/BBRI (Luc François) and Geotherwal (Robert Charlier ,ULG) concentrates on the building part and the heat exchanger performances.

2. Objectives of the project

The project aims to assess the shallow geothermal potential in Belgium through analysis of thermal properties of rocks from the surface to a depth of 150 m, which covers the standard depth for a vertical loop system currently installed in Belgium.

The first part of the project (2 years) will focus on the thermal properties (thermal conductivity and capacity) and the mineralogical composition of about 400 rock samples corresponding to 25-30 different lithologies. Thermal properties of rocks are dependent on water content, porosity, dominant mineral phase (*Diment, 1988)* and fabric anisotropy. Thermal conductivity is also a function of temperature, pressure, saturation and saturant (*Clauser, 1995; Robertson, 1988*).The sample selection will be conducted in order to be representative of the various lithologies composing the Belgian subsoil, taking into account their mineralogical composition, petrological texture along with their degree of alteration and fracturation. Thermal parameter measurements will be performed for both saturated and unsaturated conditions. A special emphasis will be given to areas with the highest geothermal needs that is the areas with highest population density (eg. Sambre & Meuse valleys and large cities of Flanders). Lithology samples will primarily be selected from the borehole collection preserved by the RBINS-GSB. This sampling will also be in accordance with Royal Belgian Institute of Natural Sciences (RBINS) collection rules and relevant data will be transferred to the databases operated by the geological collection manager. If necessary fresh samples will be also obtained from outcrops or new boreholes to assure the geographical and geological representativeness of the measurements. These will be integrated into the existing rock samples collection of RBINS-GSB.

Shallow geothermal potential maps for the Thermomap test areas (Ghent and Liège) will be produced during the second phase of the project (1 year). The construction of such maps is an innovative approach, since only two similar projects are currently conducted in Europe: in Germany, shallow geothermal potential maps are in production for the southern Molasse Basin and in the North Rhine-Westphalia (http://www.geotis.de/) ; 2) in southern Italy, the VIGOR project is under progress (http://www.vigor-geotermia.it/) (*DiSipio,2013, Manzella, 2013*).

The realisation of shallow geothermal potential (SGP) maps will be structured around the thermal conductivity results and combined with other geoscientific layers of information that will be managed through a Geographical Information System (GIS). The other sources of information will be the available geological and hydrogeological maps. The former will be transformed into a lithological map following the classification of the 25 main lithologies studied during the project. The geological/lithological and hydrogeological maps provides mainly an information at the ground surface. The extrapolation of this information to the investigated depth during the project (here 150 m) will required to be assessed with other sources of information such as borehole data, geotechnical maps and piezometric records. Finally, the validity of the SGP maps will be tested with Thermal Response Test data of available shallow geothermal systems.

3. Measurement equipment

The thermal conductivity and capacity of the rock/sediment samples will be conducted in collaboration with Erlangen University (Germany) using different devices. For fractured cores, an optical scanning method (Thermal Conductivity Scanning, TCS – (*Popov et al., 1999, 2012 ; Hartmann, 2005*) will be applied, for other rock and sediment samples a transient method will be applied (TEKAO4 and/or KD2Pro).

The Mineralogical and Petrological analyses will be conducted thanks to different analytical equipments of the Mineralogical and Petrological laboratory at the RBINS-GSB. The proportion of the different mineralogical phases of samples will be evaluated with the new Panalytical X-ray

Diffraction equipment, while the EDS (Energy-Dispersive X-ray Spectroscopy) and EBSD (Electron BackScattered Diffraction) modules will be applied in order to evaluate the chemical and micro-textural content. Special attention will be given to lithology with variable heat conductivity values to assess the influence of porosity and/or minor mineralogical phases on the heat transfer.

4. Workflow Plan: 3 years (6 semesters)

The researcher will follow this planning:

Semester 1

- Inventory of the main Belgian lithologies (25-30) based on geological data and samples selection and preparation (10-15 per lithology) from the RBINS-GSB collections
- Plan a detailed laboratory set-up/programme
- Develop project-related webpages

Semester 2 and 3

- Thermal properties measurements on dry and saturated conditions for soft and hard rock samples
- XRD, EDS and EBSD analyses at RBINS for dominant mineral phase on selected samples (when strong variability of thermal properties)

Semester 4

- Laboratory results of thermal properties analyses will be compared with available Thermal Response Test data in Belgium, values from literature and norms
- All data will be analysed statistically and correlations among parameters will be studied
- Publishing of a raw data as a Rock thermal properties table for main Belgian lithologies
- Publication of processed results in peer-reviewed journal and participation to a International conference

Semester 5 and 6

- Gathering into a GIS the geological data set (geological map, boreholes, cross-sections lithological map of OneGeology...), hydrogeological maps and catchments database, the 3D geological model of Flanders, the 3D hydrogeological model of Flanders, previous results (thermal conductivity data and map) of VITO for Flanders.
- Synthesis of existing best practices regarding shallow geothermal potential mapping
- Realisation of shallow geothermal potential maps for Ghent and Liège test-areas
- Testing phase
- Publication in peer-reviewed journal (Geothermics) and participation to European Geothermal Conference
- Communication of the results towards the Ground Source Heat Pump professional sector

5. Collaborations

The researcher will collaborate directly with:

1. VITO (Ben Laenen, David Lagrou, Sian Loveless, Belgium) for TRT data interpretation
2. BBRI/WTCB/CSTC (Luc François, Noël Huybrechts, Belgium) for connection with on-going best practices project "Smart Geotherm"
3. ULG/ Geolys/ Orex/ULB for complementarities with the on-going project "Geotherwal"
4. FAU (Christian Bialas, David Bertermann, Erlangen, Germany) or RWTH Aachen (Christopher Clauser, Germany) for rock thermal characterisation
5. BGS (John Busby, Jonathan Russell, British Geological Survey) for connection to UK data
6. BRGM (Florence Jaudin, Charles Maragna, French Geological Survey) for connection to FR data,
7. University of Padua - Institute of Geosciences and Earth Resources (E. Di Sipio, A. Manzella, VIGOR team, Italy) for best pratices example of shallow geothermal potential mapping

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