Geothermal Energy Use, Country Update for Belgium

Hans Hoes[1], Estelle Petitclerc[2], Pierre-Yves Declercq[2], Ben Laenen[3].

[1] Terra Energy, Industriezone Vlasmeer 5/0002, 2400 Mol, Belgium

[2] Geological Survey of Belgium, Jenner street 13, 1000 Brussels, Belgium

[3] VITO NV, Boeretang 200, 2400 Mol, Belgium

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1. DEEP GEOTHERMAL ENERGY IN BELGIUM

1.1 Deep geothermal resources assessment

Recent surveys on deep geothermal resources assessment were performed by VITO (*Harcouët-Menou & Laenen, 2010*) and by the Geological Survey of Belgium (*Petitclerc & Vanbrabant*, 2011, report not yet publicly available). New investigation campaigns (2D seismics, thermometry studies and 3D modelling) have been performed to assess the Belgian deep geothermal reservoirs. Two projects resulting from these studies are currently under development in Balmatt (Flanders) and in the Mons basin (Wallonia).

<u>New seismic campaigns</u>

- Flanders

Over the past 5 years, VITO completed two 2D seismic campaigns in Campine basin. The first campaign covers the area between Bree, Kinrooi and Maaseik in the northeastern corner of the province of Limburg. Geologically, the area is situated within the Ruhr Valley Garben, which is characterised subsidence during the Tertiary and bordered by active faults. The campaign consisted of 13 2D lines with a combined length of 132 km and focused on the sandstones within the Mesozoic sequence and at the top of the Westphalian.

The second campaign was completed to gain a better understanding of the geothermal potential of the Carboniferous Limestone Group. The campaign consisted of four full fold 2D seismic lines with a combined length of 51 km. The survey was located in the province of Antwerp, in the area between the towns of Turnhout, Herentals, Geel and Mol. The objectives of the survey were threefold. First, to determine the presence and depth of the Carboniferous Limestone Group, and the overall structure of the limestone strata in a depth range from 1500 to 4000 m. Second, to determine the lithostratigraphic and sedimentologic characteristics of the Carboniferous Limestone Group, in order to assess its reservoir properties (geothermics). Third, to constrain the location and position of faults and their continuation at depth. The results of the campaign were used to refine the thermal and reservoir of the Balmatt geothermal project.

- Wallonia

Two deep seismic reflexion profiles of almost 50 km in total were acquired in the Mons basin in spring 2012. The first line (Mons-1201) follows the Erquelinnes-Le Roeulx axis at east of Hainaut basin and was performed for Earth Solution project. The second line (Mons-1202) crosses the city of Mons and was realized for IDEA. The survey was carried out by DMT Gmbh (Essen, Germany) and supervised by the University of Mons.

<u>Geothermometry study and 3D model in Liege area</u>

A 3D model of the Liege carboniferous coal basin was performed by the Liege University allowing an assessment of the aquifer disposition of Visean limestones certainly present under the coal basin. More than 7000 chemical analyses of water were studied in the area of Liege-Verviers comprising the Spa and Chaudfontaine hot sources. The Na/Ca, Na/Ca/K and silica geothermometers were calculated for 630 measurements. The results show important variability due to mixing of the groundwater reservoir with the meteoritic water but some promising values were observed. This first approach demonstrates that a proper study dedicated to geothermometry (with also lithium and magnesium concentrations measurements) is necessary to go further in the interpretation.

<u>Deep reservoir cartography in Wallonia</u>

The Walloon government through the department of “Energie et du Bâtiment Durable” (DGO4) of the Wallonia Public Service (SPW) instructed the Geological Survey of Belgium to conduct a study on deep (› 300 m) geothermal resources assessment of Wallonia. This one year project consisted in 1-preparing and collecting data linked to deep geological structure and geothermal resource of the Walloon underground; 2- deducing two maps of geothermal energy interests: one for low to medium depth (300-3000 m), and the second dedicated to great depth (3000-6000 m); 3-this data will be published in next months through the cartographic portal of the SPW (DGO3).

<u>Other research activities</u>

In low temperature settings such as encountered in Belgium, large scale development of the geothermal potential is only possible in case a significant part of the produced energy can be used for medium to low temperature heating purposes. About 60% of the heat demand is this temperature range comes from heating of houses and buildings. The deployment of heating networks is an important prerequisite to cover this demand with geothermal energy, In order to deal with the cyclicity of the demand, these networks can be stabilized by including buffers at different scales or by coupling with other energy networks (e.g., smart electricity grids or gas networks).

Over the past years, VITO conducted research on the intelligent steering and coupling of hybrid energy networks with a large renewable production capacity (see also Walraven et al., this volume) and on local and centralized storage of heat (see also Verhoeven et al., this volume). The results of this research are used to define technical and business concepts for heating networks that are planned in a number of cities within Belgium. Terra Energy, together with VITO, examines under the MIP3 Flanders framework, the feasibility and potential of geothermal heat use for different sectors. Real cases are analysed in order to calculate costs and benefits, success factors and development barriers are defined.

1.2 Two geothermal power plants under preparation

Balmatt

The Carboniferous Limestone Group is one of the potential geothermal reservoirs (Berckmans & Vandenberghe, 1998). It is made up of a series of lime- and dolostones, deposited during the Early Carboniferous, some 320 million years ago. Since then, these rocks were subjected to a number of processes that have strongly influenced their porosity and permeability. This has resulted in a generally compact rock, locally cross-cut by highly permeable veins and fault zones. The Carboniferous Limestone Group was explored intensely in the western part of the Antwerp Campine. Initially, the aim was to find pockets of natural gas, but later on exploration was continued in the framework of subsurface gas storage. The data acquired during provide a good insight into the flow behaviour of water through the Limestone Group. In the western part of the Campine basin, the lime- and dolostones constitute local reservoirs that are characterized by a high to very high permeability and a small accessible pore volume. Pressure communication between reservoirs, separated by a considerable distance, reveals the high permeability zones are connected with each other over a large part of the area (Vandenberghe et al., 1987).

Starting from the existing data, VITO examined the possibility to use the Carboniferous Limestone Group as a heat source for a geothermal plant. It's VITO's intension to built the geothermal plant on the Balmatt industrial brown field near Mol. At that site, the Carboniferous reservoir is located between 2.800 to 3.800 m depth. The estimated temperatures range from 120°C at the top of the reservoir to 142°C at the base. The average production temperature is estimated at 124°C. Based on production tests from nearby wells, the likely flow rate (p75) of a well is estimated at 175 m^3/h. The combined production of two or more well, estimated to be in the range of 30 to 38 MW_{th}, will be used to drive an ORC and the feed a local heating network.

Mons

The 29 september 2011, the Walloon government decided to support two pilots-projects in the Hainaut basin. The first one consists in developing a district heating in the Mons station area (explained below). The second project, more ambitious, concerns the development of a geothermal power plant in the south of the Mons agglomeration. The main objective is to reach the reservoir of Devonian limestones at a depth between 4.5 and 5 km.

1.3 Geothermal district heating plant

Deep direct use of geothermal energy is currently limited to the district heating system in the area of Mons.

Saint-Ghislain and Douvrain wells

Deep geothermal energy is exploited in the Hainaut basin since 1986. IDEA, an intermunicipality manages the local production of geothermal energy. There is three existing wells: Saint-Ghislain, Douvrain and Ghlin. Saint-Ghislain was first an exploration borehole performed for the Geological Survey and was converted in 1986 into a geothermal well. The anhydrite permeable layer in underlying breccia (artesian flow; 100m³/h) was reached at 2500m with a temperature of 73°C in Mississipian limestones (Dinantian). The Douvrain and Ghlin wells were drilled to confirm the extension towards the North and Northeast of the geothermal reservoir, and only anhydrite traces were detected. This complex reservoir located under Mesocenozoïc deposits of the Mons Basin, and under coal-beating sediments of Upper Carboniferous was modelized by Licour in 2012 (Licour, 2012) The productive layer in the same breccia than Saint-Ghislain give a water of 67°C with a artesian flow of 100m³/h at a depth of 1350m for Douvrain and 1550m for Ghlin. This latest one, never exploited until now, will be soon put into operation.

The Saint-Ghislain heating plant provide heat for 355 social housing, 3 schools, 1 hospital, 1 sport center, 1 swimming pool, the train station. Greenhouses and the water treatment station are the secondary users of the heating plant. With a geothermal capacity of 6.1 MW_{th}, the plant delivers 16.7GWh of heat and avoids 5.500 tons of CO_2 emissions per year.

Mons station

IDEA is looking for new application of earth heat at a depth of 2500m in the Dinantian limestones aquifer. The new geothermal plant should delivered 6MW_{th}. The investment of 6 MEUR will supported half by the Walloon government. IDEA and the city of Mons will pay the rest. Exploitation wells are planned to be drilled in 2013, nearby the new railway station of the city of Mons.

2. SHALLOW GEOTHERMAL ENERGY IN BELGIUM

2.1 Current market and evolution by 2015

Shallow indirect use through heat pumps is developed in both Flanders and Wallonia and the market for heat pump installations recently has grown slowly, but surely. The number of installed GSHP in Belgium in 2010 was 13085 with a capacity of 142MWth (EurObserv'ER, 2011). The Belgium market of GSHP in the residential market is growing with about1486 units in 2011 and 1587 units in 2012. The residential market has been growing steadily over the past few years. For 2013, a decrease in installed GSHP is expected as the number of building projects is diminishing due to the consequences of the financial crisis.

It is expected that GSHP market will raise again in 2014 in Flanders as a more restricted obligation on the energy level of new built constructions is elaborated. Moreover, a certain minimal share of the required energy needs to be renewable. It is expected that in 2015 about 2500 units will be installed, this is a conservative estimation as impact of the new legislation is difficult to define.

New medium to big size buildings in public sector (hospitals, rest homes, local governments,…) are equipped in many cases with a GSHP system providing heating as well as cooling resulting in payback times of 5 to 10 years.

2.2 Shallow geothermal potential

For several decades, GSHP development in Belgium was limited to some dozen horizontal loop systems for mainly residential applications. Nowadays, 80% of the systems are estimated to be vertical loop (or BTES) systems. A limited number of projects uses open loop (or ATES) systems (estimation of 5%), the rest (± 15%) concerns horizontal loop systems. Vertical loop systems are considered as the most convenient technology for large scale future development of GSHP's as they offer specific benefits (easy to install, good efficiency, less dependent on geological circumstances, …).

In public, commercial and horticultural sector, both ATES and BTES systems are implemented in Flanders. The open loop systems using pumped groundwater are the most profitable in larger applications with high heating and cooling demands (e.g commercial buildings). But in regions with geological restrictions for ATES systems, BTES can be seen as an economic feasible alternative. Until recently, mainly single house applications were realized. Nevertheless, the successful implementation of integrated geothermal solutions for projects in the agriculture and public/commercial building sector has proven the enormous potential for green heating and cooling combined with energy savings and high comfort levels. As Belgium shows complex geology all kinds of GSHP types (as well as excellent expertise on geology and design) are necessary in order to obtain good technology development.

In recent years VITO has been exploring the technological possibilities and feasibility of geothermal energy in series of research projects.

The ThermoMap project (Area mapping of superficial geothermic resources by soil and groundwater data) is an EC co-funded project (FP7-ICT Policy Support Programme) in which the Geological Survey of Belgium is the Belgian partner. Thermomap focuses on the mapping of very shallow geothermal energy potentials (vSGP) in Europe (www.thermomap-project.eu). The city of Liège was selected among others cities in Wallonia based on its growing economic clout and expected population rise. The vSGP is estimated using the Kersten formulas (Kersten 1949) for three ground layers: 0-3 m , 3-6 m and 6-10 m. Using this approach, the annual mean temperature, precipitation, groundwater saturation and the grain size are taken into account to calculate for each layer the thermal conductivity (λ in W/mK). The thermal conductivity values for 0-3m layer are mainly considered as medium low 1 W/mK, (loam/unsaturated) north of the river Meuse. Toward the south some area are characterised by medium and high conductivity resulting from saturated subsoil. For the 3-6 m and 6-10 m layers when hard rocks (banning the installation of horizontal systems) are not present, the thermal conductivity is evaluated as medium to high for all the remaining test area. In Flanders, an area of 1600Km² surrounding the city of Gent was selected and the thermal conductivity of the 3 layers was also evaluated using the same methodology. The conductivity values for the 0-3 m layer stretche from a low 1 W/mK (loam/unsaturated) in the southern part of the study area to medium high 1.4 W/mK (sandy loam/saturated) in the northern part. For the 3-6 m and the 6-10 m layers the λ are considered as high with values reaching 2.5 W/mK for the 6-10 m (sandy loam/saturated). On more elevated areas the 3-6 m layer shows a lower λ related to more clayey sediments occurring at this depth as a result from the buried Tertiary topography.

2.3 Major barriers for full implementation

In Belgium, several barriers that prevent extensive implementation of GSHP systems can be defined. At first, geothermal expertise is limited, geological variability is high and trained designers are scarce. Secondly, payback times are high, certainly for residential housing where the restricted financial support has minor influence on the feasibility. Third, a trend to passive housing goals for zero energy housing without additional or with very limited heating. In latter case, GSHP's can't deliver enough energy and are therefore not feasible. Furthermore, environmental permits have many restrictions and are very different according to the different regions of the country.

2.4 Perspectives in R&D

Smart Geotherm

Thermal energy can be stored in the soil for a long period. Although the focus lays on geothermal energy, other sources of thermal energy in the project are considered in order to regenerate the soil thermally or to provide this energy in the short or longer term after buffering. Thermal energy can indeed be stored for a shorter period of time in the structure of the building (known as concrete core activation) or in flexible buffers as containers filled with water or Phase Change Materials of Thermo Chemical Materials.
Particular attention will be paid to underground structures such as pile foundations which are integrated with heat exchangers. These energy piles combine both the bearing and exchanging energy function.
In the Smart Geotherm project, a dynamic control algorithm will be developed to meet the need for cooling or heating and to match the supply of thermal energy with the buffering capabilities. This algorithm will be validated during the project with the monitoring data of pilot projects.Besides the part of research and development, much of the time and energy will be spent on the transfer of knowledge of geothermal energy to the market. Flanders has indeed a big catch up regarding the use of this form of renewable energy. Together with partners, guidelines, codes of good practice, demonstration projects, etc. will be developed and disseminated to the market.

Geotherwall

The Geotherwall project is a 4 years project, which started in 2011, financed under the umbrella of ERABLE (Énergies Renouvelables) program of the Walloon Region . Geotherwall focuses on the optimization of closed-loop Borehole Heat Exchanger (BHE) at 100-200 m depth. The main objectives consist in maximizing the thermal transfer between the pipes and the ground by analysing the impact of the geometry of the BHE and the influences of the grouting material. In order to evaluate and optimize the performance of the geothermal system, the global problem is decomposed into two sub-problems: the near-field behaviour (at the level of the borehole heat exchanger) and the far-field behaviour (in the surrounding ground). The performances of the geothermal system are also evaluated by 3 aspects that are developed in this project:

- laboratory tests for characterization of the properties and responses within the well;
- in situ tests in geological drilling with advanced instrumentation;
- detailed analysis of these results with numerical simulations at small and large-scale with a finite element code.

Temper

In Belgium the heat is commonly extracted by closed vertical loop systems. A major barrier to full implementation of the shallow geothermal potential is the frequent overdimension of projects due to poor knowledge of ground conditions. This leads to unfavourable cost comparisons and abandonment of many promising projects. Studies in Sweden, Germany and Switzerland demonstrate that the proper design of geothermal installations depends on sufficient and precise characterisation of thermal properties of the ground. Currently the thermal properties of rocks (heat conductivity and heat capacity) used by the designers of heat probes in Belgium are provided by reference tables from French, German and Swiss studies which may not be directly applicable to the Belgium subsurface.

The Geological Survey of Belgium and VITO decided to introduce a common research project focusing on following objectives: (1) Characterise the thermal and geomechanical properties of Belgian subsoil by laboratory analysis of representative Belgian rocks from borehole samples available from collections of the Royal Belgian Institute of Natural Sciences (2) Calculate and map the thermal conductivity for the entire territory of Belgium. (3) Demonstrate how these parameters influence the design of closed vertical loop installations and consequently the drilling costs.

3. CONCLUSIONS

Today, only one deep geothermal energy system (since 1985, in Saint-Gislain) is still in operation. All other systems, developed in the 80's in Flanders, are closed. After many decades of very limited activity on deep geothermal energy development, nowadays different initiatives are deployed for both power and thermal energy production.

Shallow geothermal energy installation numbers are growing steadily, but far behind the neighbouring countries. Main reason is the rather high investment with long payback times at residential housing. Medium to big size systems are becoming important, certainly when providing heating and cooling. These systems can benefit also from better support measures.

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Tables A-G

Table A: Present and planned geothermal power plants, total numbers

	Geothermal Power Plants		Total Electric Power in the country		Share of geothermal in total	
	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (%)	Production (%)
In operation end of 2012	-	-	20019	90427	0%	0%
Under construction end of 2012	-	-	20019	90427	0%	0%
Total projected by 2015	8	55	18004	87741	0,044 %	0,063 %

Table B: Existing geothermal power plants, individual sites*

*Geothermal power plants are not yet available in the country.

Table C: Present and planned geothermal district heating (DH) plants and other direct uses, total numbers

	Geothermal DH Plants		Geothermal heat in agriculture and industry		Geothermal heat in balneology and other	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2012	6,1	16.7	0.9	1,3		
Under construction end of 2012	-	-	-	-	-	-
Total projected by 2015	42	68	-	-	-	-

Table D: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name	Year commiss.	Is the heat from geo-thermal CHP?	Is cooling provided from geo-thermal?	Installed geotherm. capacity (MW_{th})	Total installed capacity (MW_{th})	2012 geo-thermal heat prod. (GWh_{th}/y)	Geother. share in total prod. (%)
Saint-Ghislain	Saint-Ghislain	1985	No	No	6,1	11	18	55

Table E: Shallow geothermal energy, ground source heat pumps (GSHP)

	Geothermal Heat Pumps (GSHP), total			New GSHP in 2012		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2012	16158	213,0	335,1	1587	38,6	15%
Projected by 2015	22007	297,2	462,5			

Table F: Investment and Employment in geothermal energy

	in 2012		Expected in 2015	
	Investment (million €)	Personnel (number)	Investment (million €)	Personnel (number)
Geothermal electric power	-	-	67	3
Geothermal direct uses	-	-	11	-
Shallow geothermal	27,3	122	54	190
Total	27,3	122	132	193

Table G: Incentives, Information, Education

	Geothermal el. Power	Geothermal direct uses	Shallow geothermal
Financial Incentives – R&D	Very limited to support one year project on deep geothermal resource assessment in Wallonia. In Flanders, R&D in innovative geothermal applications can get support through the Agency for Innovation by Science and Technology.	One regional program : MIP3 – GEO.HEAT	Two regional projects: Smart Geotherm and Geotherwall. One European: ThermoMap
Financial Incentives – Investment	In Flanders geothermal projects can get up to 30% financial support (for SME's) through the energy ecology plus subsidy	In Flanders geothermal projects can get up to 30% financial support (for SME's) through the energy ecology plus subsidy. Limited support for industrial applications possible through the Flemish Energy Agency;	In Flanders geothermal projects can get up to 30% financial support (for SME's) through the energy ecology plus subsidy. Limited support for industrial applications possible through the Flemish Energy Agency;
Financial Incentives – Operation/Production	In Flanders: green power certificates (90 Euro/MWh for 15 years)	Available but insufficient in Hainaut basin	
Information activities – promotion for the public	–	Very limited (seminars, brochures in the Hainaut basin) INTERREG IVC GEO.POWER project INTERREG Vlaanderen Nederland GEO-HEAT APP project	INTERREG IVC GEO.POWER project VIS -Smart-Geotherm project
Information activities – geological information	From the GIS of the Walloon region From DOV for Flanders	From the GIS of the Walloon region From DOV for Flanders	Through the GIS of ThermoMap for very shallow geothermal syst.
Education/Training – Academic	-	-	Geotrainet under preparation
Education/Training – Vocational	-	-	-

Key for financial incentives:

DIS	Direct investment support	RC	Risc coverage	FIP	Feed-in premium
LIL	Low-interest loans	FIT	Feed-in tariff	REQ	Renewable Energy Quota