Overview and perspectives on shallow geothermal energy in Belgium

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ABSTRACT

The current energy transition towards Renewable Energy Sources (RES) in Europe is mainly driven in Belgium by wind turbines and photovoltaic panels. However Ground Source Heat Pumps (GSHP) has not yet reached the full attention of Belgian authorities and customers while the potentialities in the country for heating/cooling market by GSHP for housing and micro- to medium-sized enterprises are important. The specificities of the Belgian market, especially the attractiveness to install GSHP for individual housing is related to various socio-economic factors. The main barrier to the relatively slow growth rate with respect to other forms of RES can be partially explained by the estimated extra-cost. This is due to frequent overdimensioning of shallow geothermal systems during the design phase. These overestimations could be addressed by the improvement of data accuracy of thermal parameters of geological formations in Belgium. Various geothermal projects acting for the development of shallow geothermal energy, as well as its perspectives tackles the different technical and administrative barriers.

1. INTRODUCTION

In 2009, the European Union adopted the Energy & Climate Package to fight against climate change (http://ec.europa.eu/clima/policies/package/index_en.htm). This package sets ambitious energy and climate targets for 2020: 20 % reductions in greenhouse gas emissions from 1990 levels; raising the share of EU energy consumption produced from 20 % of renewable resources as well as in energy efficiency. An additional target set by the European authorities (Energy efficiency Plan 2011 adopted 8 March 2011: (http://ec.europa.eu/energy/efficiency/action_plan/action_plan_en.htm) is that by 2021 all new European buildings shall be near “zero energy” consumption, obliging them to generate their own energy.

In this paper, we first present the market potentialities for heating/cooling of housing and enterprises in Belgium. The national and regional energy policy regarding of the share of RES at the year 2020 horizon is then briefly described. The significance of well-dimensioned GSHP based on reliable and representative thermal parameters of local geological formation is also emphasized. Finally, the various initiatives and projects financed by regional or European funding and related to shallow geothermal energy are then described.

2. MARKET CHARACTERISTICS

The size of Belgium (only 30,528 km²) and its high-density population (354.7 inhabitants/km²) could be regarded as an hurdle for the development of the shallow geothermal energy market, at least for individual housing. In fact, the installation of shallow geothermal energy systems (vertical or horizontal loops) require the access to at least a given area of ground. However, the past and existing town planning regulations combined with the socio-economic parameters provides interesting information regarding the market potentialities of the shallow geothermal energy in Belgium.

For instance, the ‘EU energy trends to 2030’ report published by EU Directorate-General for Energy (http://ec.europa.eu/clima/policies/package/docs/trend s_to_2030_update_2009_en.pdf) following demographic and macroeconomic assumptions pointed out that the population in Belgium will increase by 8.3% between 2010 and 2030. By contrast, the average household size will decrease from 2.3 persons in 2010 to 2.1 persons in 2030. As a result the number of households in Belgium will increase from a current level of 4.7 million to 5.5 million, corresponding to an increase of ~ 17%. Even if the insulation of houses is improving greatly there will be in the future a need for more energy sources.

Furthermore the housing market in Belgium is still strongly driven by the construction of individual household. With this respect, dwelling type statistics from Eurostat (2010) indicate that for the 27 EU member states, 41.8% of population in average lived in flats, 34.4% in detached houses and 23% in semi-detached houses. The situation is different in Belgium where flat accommodation represents only half EU-average with a proportion of 20.3%, while semi-detached and detached houses occupies large land-areas with a proportion of 41.7% and 37.4%, respectively. This land-consumption distribution is related to inefficient approaches for land use planning policies that led to a poor control of urban sprawl in Belgium (Halleux et al., 2012). Such urban sprawl corresponds to the development of large areas with low density population around the major cities (European Environment Agency, 2006). This phenomenon is observed in many areas with high population density, but it is particularly significant in Belgium, North of France, Luxembourg and NW Germany. Even if this lack of control has major negative environmental and socio-economic impacts, such as the reduction and fragmentation of agriculture lands and the necessity of development of important transport infrastructures, it also paradoxically points out that the potentiality of development of shallow geothermal energy in Belgium for heating and cooling of individual housing is one of the most promising in Europe.

The potentialities of development of shallow geothermal energy for micro-, small and medium-sized enterprises in Belgium follow more closely the European trend, since the proportion of these different enterprise size classes (from micro- to large enterprises) in Belgium is close to the EU-27 average according to the business size classes reported by Eurostat in 2008. With this respect the bulk of the enterprises in Belgium, as anywhere in Europe, correspond to micro-companies (92.5%) or small enterprises (6.3%). Shallow geothermal systems could therefore provide the heating and cooling energy requirements for a potential market of about 420,000 micro- to small-companies.

The previous analyses do not take into account the socio-cultural, sport infrastructures or greenhouses installations, but they indirectly reflect the land use planning or enterprises.

3. ENERGY POLICY AND TECHNICAL ISSUES

In 2005, RES accounted in Belgium for less than 2.5% of energy production (CONCERE-ENOVER 2010). Nevertheless, the National Renewable Energy Action Plan defined ambitious goals for 2020 of 13% of total energy consumption in Belgium produced from RES. The targets for the different forms of energy needs are however different: 20.9 % of electricity needs will have to be produced in 2020 from RES, while the latter will represent for heating/cooling and transport demands: 11.9% and 9.0%, respectively (Fig. 1). So far, efforts to reach this target were focussed on increasing electricity production based on RES, mainly from wind and PV. Heat production based on RES is much less a topic although heating is good for 48% of Belgium's primary energy consumption. It is technically feasible to cover up to 50% of this demand by geothermal (Devogelaer et al., 2012). The heating/cooling demand represents 48% of the total energy consumption in Belgium and shallow geothermal energy will therefore have to contribute significantly to reach the 2020 targets.

The geothermal energy sector in Belgium is at the moment still very limited. Historically, the use of medium deep (700 – 2500 m) geothermal energy by means of heat pumps was introduced in the 1950ies (Berckmans & Vandenberghe, 1998). In the Mons Basin (W Belgium) the Saint-Ghislain project of district heating has survived the ups and downs of the energy prize (Delmer et al., 1996; Licour, 2012).At Chaudfontaine near Liège, natural hydrothermal sources at a temperature of 36.6°C combined with boreholes are operated mainly for bottled mineral water. This hydrothermal site also provide warm water for a public swimming pool.

Recent studies on deep geothermal resources assessment were performed by VITO in Flanders (Harcouët-Menou and Laenen 2010) and by the Geological Survey of Belgium for the Walloon Region (Petitclerc and Vanbrabant 2011). Two projects related to these studies are currently under investigations, at the Balmatt site in Mol (Flanders) and in the Mons basin (Wallonia).

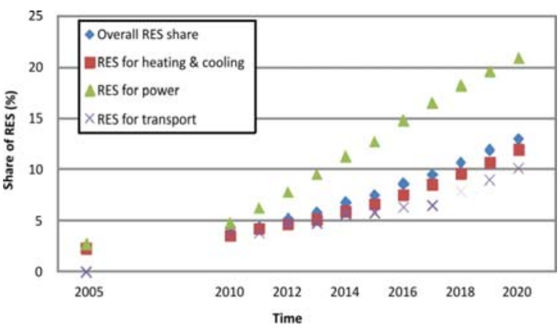

Figure 1: 2020 target for Renewable Energy Sources and planned trajectory for Belgium (CONCERE-ENOVER 2010)

Shallow geothermal energy using heat pumps, as well as Aquifer Thermal Energy Storage and Borehole Thermal Energy Storage made a slow start. They came under steam since a few years but still have a long way to go to realize their full potential. Around 75% of the GSHP installed in Belgium are vertical loops. In 2011, the market for heat pump installations has grown slowly but surely (+12%).

A limitation to the development of shallow geothermal energy in Belgium is linked to the administrative complexity of the energy policies in each region (Flanders, Wallonia and Brussels Capital). In fact, the Energy Policy in Belgium is shared between the Federal level that is in charge for the technically and economical indivisible subjects (large power infrastructure, nuclear energy,...), while the regional authorities manage, amongst other topics, smaller energy infrastructures, as well as the new sources of energy (National Plan for Renewable Energy, 2010: http://economie.fgov.be/en/consumers/Energy/Renewable_energy/#.UWbd5bVATnh). The professional agreements, the regulations and the incentives for RES, including shallow geothermal energy, follow therefore different approaches in each region.

Besides the policy aspects, the European Technology platform on Renewable Heating and Cooling pointed out that: “the key challenge for the widespread use of geothermal heat will be the ability to reliably design, engineer and control ground source heat pumps installations, in order to be able to use the year-round potential of geothermal energy for sustainable heat and cold supply” (Sanner et al., 2011).

A major barrier to full implementation of the shallow geothermal potential in Belgium is effectively the frequent overdimension of projects due to poor knowledge of accurate local ground conditions. This leads to unfavorable cost comparisons and occasional abandonment of promising projects. Studies in Sweden, Germany and Switzerland demonstrate that the proper design of geothermal installations depends on sufficient and precise characterization of thermal properties of the ground. The principles of thermal conductivity measurement of hard and soft rocks is rather well understood (Beck 1988, Diment & Pratt 1988, Robertson 1988, Gustafsson 1991, Clauser 1995, Popov et al. 1999, 2012, Gehlin 2002; Wagner 2005, Acuña.&.Palm 2012, Acuña 2013,) but their application is often inappropriate. Current practice in design of borehole heat exchangers for small, individual applications in Belgium is actually based on empirical values and guidelines for rock thermal properties from Germany, France or Switzerland. However, the local geological context may be quite different (e.g. the fold-and-thrust belt in the southern part of the country). For instance, heat conductivity values for limestone formations provided by French (Demongodin et al. 1991) and Swiss (CREGE 2008) tables are calculated typically for Jurassic limestones. The bulk of limestone rocks in Belgium are of Palaeozoic age, and their mineralogy content and diagenesis evolution differ strongly from the Jurassic carbonates. These limestones are not compatible in terms of thermal and geomechanical properties.

A proper knowledge of the effective heat transfer between the transport medium and the rocks in the underground is crucial in the design of heat or energy storage to optimize performance for cost (Sanner, 2001, Gehlin 2002, Acuña, 2013). Nevertheless, large differences in design show up between different developers for the same type of project. This has two reasons, a lack of knowledge on the thermal characteristics and an insufficient analysis of the thermal energy demand profile of the building, resulting in big uncertainties on the design. One of the major barriers that obstruct an efficient design is the limited availability of reliable maps on thermal characteristics of the underground. Whilst it is viable for larger enterprises to conduct in-depth investigations into the site properties for shallow geothermal application, such costs are generally prohibitive for individual residences and small to medium sized enterprises (SME’s), which represent the bulk of the potential market.

4. ON-GOING PROJECTS

The previous issues are currently addressed through a series of projects conducted by different actors, including private companies, regional or federal research institutes, universities and professional associations. These projects are financed by either regional or European funds.

4.1 Regional research projects

Smart Geotherm

This project focuses on the “Mobilization of the storage of thermal energy and the thermal inertia of groundbased concepts for the intelligent heating and cooling of middle-sized and large buildings”. Smart Geotherm is a 6 years project running from 2011 until 2017. It is supported by IWT Flanders agency for Innovation through Science and Technology.

The Belgian Building and Research Institute takes the leading part in this project. The other partners are Vlaamse Confederatie Bouw and Bouwunie (Flemisch building associations), FEBE and infobeton (concrete building associations), ABEF (association of foundation companies), VITO (Flemish institute for technological research), KULeuven (University of Leuven). The main objectives are (1) Promoting the use of shallow geothermal energy in middle-sized and large buildings (2) Transfer of knowledge of geothermal energy by the initiation of codes of good practice, seminars, lectures (3) Development of predictive modeling and validation of this model by case studies (4) Promotion of innovations in geothermal concepts and storage of thermal energy.

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 is 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 and demonstration projects will be developed and disseminated to the market.

GeoTherwall

The GeoTherwall project is a 4 years project, which started in 2011. It is financed under the umbrella of ERable (Énergies Renouvelables) program of the Walloon Region. The University of Liège is managing GeoTherwall, the University of Brussels and two private companies OREX and Geolys are partners in this project. 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.

4.2 European research projects

ThermoMap

The Geological Survey of Belgium 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. this volume). Thermomap focuses on the mapping of very shallow geothermal energy potentials (vSGP) in Europe (www.thermomap-project.eu). For Belgium, two test-areas centered around the cities of Gent and Liège were selected, based on their growing economic clout and expected population rise. The selected test areas are representative for the different geological and geographical settings within Belgium . The Flanders flatland in the north (Gent) is represented by flat lying Tertiary sands and clays, and the more hilly terrain in the south (Liège) which is built on folded bedrock, occasionally covered by a thin veneer of chalks. 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). In Gent for the 0-3 m λ values stretches 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.

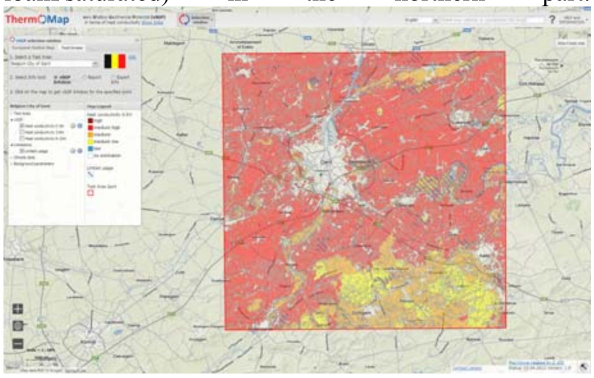

Figure 2: Thermal conductivity (W/mK) for the 0-3m ground layer in Gent.

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.

In Liège, the λ values for 0-3 m are mainly considered as medium low 1 W/mK, (loam/unsaturated) and in the South some areas are characterised by medium and high conductivity resulting from a saturated subsoil. For the two deeper layers, the major difference with Gent is related to the appearance of hard rock at these depths banning the installation of horizontal systems.

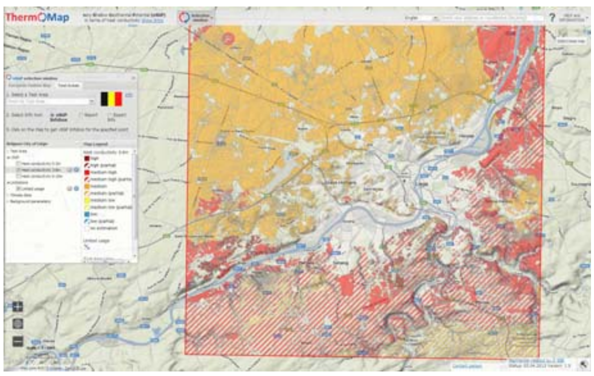

Figure 3: Thermal conductivity (W/mK) for the 3-6m ground layer in Liège.

For the two test areas, representative soil samples have been collected on the field and texture measurements were realised in the laboratory in order to verify the estimated grain size coming from the available data. 5

boreholes out of 7 show texture similar to the estimation. The table 1 shows the grain size measurement (referred as the USDA texture class) for two boreholes; one in Gent (Balegem) and the other in Liège (Seraing). In Balegem, the texture matches the estimation until the depth of 2.2 m, deeper there is a difference between the measure and the estimation (from silt loam to sandy clay). In Seraing, the measure differs directly from the estimation but the difference is not much; from sandy loam to loam.

Table 1: Examples of grain size measurements and corresponding texture for two boreholes.

Location	Depth [m]	Initial weight for measurement [g]	Sand (corr.) [%]	Silt [%]	Clay [%]	USDA texture class	Weighted USDA texture class for respective depth layer
Balegem (BAL)	0,35 - 0,45	17.69	17.4	65.2	17.4	silt loam	silt loam
	0,85 - 0,95	18.0127	23.2	62.8	14	silt loam	silt loam
	1,40 - 1,50	18.9344	54.2	30.6	15.2	sandy loam	silt loam
	2,10 - 2,20	18.4675	4.9	77.6	17.5	silt loam	silt loam
	3,40 - 3,50	18.3716	11	67.1	21.9	silt loam	sandy clay
	3,70 - 3,80	23.1239	51	30.8	18.2	loam	sandy clay
Seraing	0,95 - 1,05	18.0493	64.5	24.8	10.7	sandy loam	loam
	1,45 - 1,55	17.1821		75.4	24.2		loam
	2,00 - 2,10	18.1195	3.3	62.9	33.8	silty clay loa	loam
	2,20 - 2,30	18.4499		50.7	49.1		loam
	2,30 - 2,40	17.8286	21.8	20.4	57.8	clay	clay
	2,75 - 2,85	17.6053	47.4	9.8	42.8	sandy clay	clay

Regeocities

The Regeocities project is focused on the achievement of the National Renewable Energy Action Plan geothermal targets 2020 marked by countries with ambitious objectives regarding GSHP by means of the removal and clarification of the non-technical administrative/regulatory barriers at local and regional level. The project aims to overcome barriers by means of reliable knowledge about the market conditions and barriers for geothermal heat pumps in the targeted countries (cities and regions) and in the general European framework (De Boever et al. 2012). This is realised by identification and transferring of good examples of regulatory frameworks and administrative routines from mature to juvenile regions. The project will result in both recommendations to develop a common pre-normative framework and education and knowledge transfer in order to develop the tools for training energy managers in local authorities and Helpdesk for municipalities, and public authorities. Municipalities and regions in the participating countries are engaged in the project to secure a good implementation of the project results.

Geotrainet

With the objectives of zero energy consumption and carbon emissions training activities have a major role to play in the next few years The recognition and accreditation of the training are also considered as key aspects for the success of such transformation. The project GEOTRAINET, "Geo-Education for a sustainable geothermal heating and cooling market", anticipated these training needs. The project was supported by the EU in the frame of the Intelligent Energy for Europe (IEE) program during the period 2008-201 The objective of this project was to develop European Education programme as an important step towards the certification of geothermal installations. From the different groups of professionals involved in a GSHP Two targets group were selected: designers and drillers. 1. The project finished with important outcomes: education programme comprising curricula for designers and drillers on shallow geothermal facilities, didactic materials, training structure at European level as a basis for the proposed GEOTRAINET certification structure, and important training experience in 8 European countries.

The vision of the GEOTRAINET consortium was that the training and certification programs will be recognised all over Europe and provide benchmark standards for consistent voluntary further education in the field of shallow geothermal in all participating countries. With this objective several workshops were held since October 2011 to start the real-life existence of the Geotrainet program.

The decision was creation of an independent organisation, GEOTRAINET AISBL, to host the components of the European structure. This new organisation, to be sustained by EFG and EGEC, as well as national members, will hopefully be operational early in 2013. GEOTRAINET organization, today, has 13 members, two European members, and 11 national members: Belgium is represented by Belgian Building Research Institute

The main Tasks of the National Training Coordinator are:

• Implementation of the international training standard and definition of specific adaptations needed at national scale

• Report to international education committee considering required amendments and adaptations of training standard

• Notification of any changes of training system to national training institutes

• Dissemination of training program at national level

• Communication to national training institutes

• Keeping the quality standards on national level

5. PERSPECTIVES IN BELGIUM

In order to overcome the current setbacks to full scale implementation of GSHP in Belgium, the knowledge base for the industry has to be improved, which can be realized by research and dissemination on relevant parameters in the following way: (1) characterize the thermal and geomechanical properties of Belgian subsoil, (2) calculate and map the thermal conductivity for GSHP for the Belgian territory, (3) show how these parameters could influence the design of closed vertical loops installations, and consequently the drilling costs, with case studies in two very different geological contexts, (4) combine the geological, hydrogeological, thermal and geomechanical properties data into a public web portal application to allow the interactive consultation of shallow geothermal potential maps (thermal conductivity map). A validation of the thermal conductivity map will be a key part of the study. This will reveal its accuracy and potential weaknesses; – factors that are vital in order for the end users to have confidence in its results and reduce risk when looking to its practical application. This is especially important since shallow geothermal projects often initially require a substantial investment. It will provide evidence in which decision-makers and end user groups may have confidence in.

There is an urgent need for further clarification of the regulations for shallow and deep geothermal applications, to obtain an integrated and consistent set of regulations for exploration, exploitation, monitoring, or possible subsidiary schemes. For GSHP's and shallow geothermal systems, different stakeholders have united in the "Platform Heat Pumps" and in the Association Geothermy. Especially the last one should play an important role in the discussion on the legislative framework for GSHP's, shallow and deep installations

VITO will take the initiative to initiate the GEO. Platform. The main objective of this platform will be a coordinating role in the research exploration of the subsurface in Belgium to a more efficient use of the resources and to achieve an exchange of research results.

Indeed, the best way to convince potential investors is to show that shallow geothermal applications can be implemented in a reliable and economically feasible way. Although many projects are already running, good documented cases which are carefully monitored and well documented over long periods of time are rare. Monitoring needs extra funding which is often not foreseen in the initial project. Allocation of specific funding for monitoring (measurements) and dissemination (technical and vulgarizing publications) of Best Practices are a good way to promote geothermal energy applications.

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